# DEVELOPING GIS-BASED WEIGHTS OF EVIDENCE PREDICTIVE MODEL OF PRE-COLUMBIAN SITES IN TRINIDAD

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2003

Dedicated to my wife Joan and our son Gavin, both of whom have been with me through thick and thin.

# ACKNOWLEDGEMENTS

This dissertation would not have been possible without the invaluable assistance of the following persons. First, I wish to thank my academic advisor, Professor William Keegan, for his astute supervision of my dissertation research as well as for providing requisite funding for my graduate studies at the University of Florida. I am also grateful to the other members of my Ph.D. committee, Drs. Kenneth Sassaman and Steven Brandt as well as Professor Michael Binford, for their thoughtful comments at various stages of my dissertation research. I owe a debt of gratitude to Mr. Jeff Senior for his unrelenting moral support during my studies at the University of Florida. I am also grateful to Professor Patrick Bryan of the History Department of the University of the West Indies (UWI), Mona, Jamaica, for actively encouraging me to pursue archaeology as a viable career path when I was a 19-year old undergraduate history student at UWI. While I was a graduate student in archaeology at the University of London, Institute of Archaeology (1986–1987), it was the academic acumen of both Professors Peter Drewett and Warwick Bray that inspired me to pursue prehistoric archaeology as my area of specialization.

Many thanks go to Dr. Brinsley Samaroo, head of the History Department, U.W.I., St. Augustine, Trinidad and Tobago, for providing both logistical and moral support during my dissertation write-up. I am also grateful to Dr. Jacob Opadeyi, Senior Lecturer in the Survey and Land Information Department, U.W.I., St. Augustine, for his thoughtful comments regarding the incorporation of GIS applications in my research. I profusely thank Dr. G. Bonham-Carter, the designer of the weights of evidence ArcView

extension, for always being ever so willing to provide useful advice on weights of evidence modeling whenever I needed it. Thanks go to Mrs. Rudylynn DeFour Roberts, Historic Preservationist, Ms. Charmaine Taylor of the Historic Restoration Unit (Ministry of Works), Professor Keith Laurence, and Mr. Boswell John, Chairman and Secretary of the Archaeological Committee, respectively for kindly furnishing me with valuable information on cultural resource management of archaeological sites in Trinidad.

I also gratefully acknowledge the contribution of Nku Timothy, a recent graduate in the Department of Surveying and Land Information of U.W.I. St. Augustine, who, under my supervision, produced a variety of layouts, tables and other graphics for the dissertation. Davin Singh, an undergraduate student of U.W.I., St. Augustine also deserves commendation for assisting with the compilation of a list of all known pre-Columbian sites in Trinidad, the latter of which were extracted from a miscellany of files and site records in the Archaeology Centre. Ms. Jacqueline Williams of U.W.I., St. Augustine should also be profusely thanked for ably editing and formatting this dissertation. Last but certainly not least I gratefully acknowledge the sterling contributions of my wife, Joan, our son, Gavin, and my mother, Mrs. Melrose Reid, whose unflagging support and active encouragement were absolutely critical to the successful completion of my Ph.D. program at the University of Florida.

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ABSTRACT

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements of the Degree of Doctor of Philosophy

DEVELOPING A GIS-BASED WEIGHTS OF EVIDENCE PREDICTIVE MODEL OF PRE-COLUMBIAN SETTLEMENT SITES IN TRINIDAD

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May 2003

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Aimed at enhancing cultural resource management of Trinidad's pre-Columbian sites, on the basis of GIS weights of evidence, this dissertation has produced archaeological site predictive models for Cipero, South Oropouche and Restnorth, three watersheds in the south and southwest of the island. Weights of evidence analysis of prehistoric archaeological sites and their areal association with evidential themes such as landform, relief, soils and land capability formed the basis upon which predictive models were generated. The study suggests that pre-Columbian archaeological sites in south and southwestern Trinidad are likely to be found in areas with hilly relief, land capability characterized by either fairly good land or land unsuitable for agriculture due to slope and/or water limitations, upland landforms and in areas with "free internal drainage soils" along the south coast of the island.

The archaeology of Trinidad has invariably been characterized by little or no information about inter-site spatial relationships as well as the relationships among sites and the biophysical properties of the landscape on a regional scale. Given these realities, this GIS-based dissertation was necessary, as it provided predictive models for more clearly understanding the spatial relationships between pre-Columbian sites and Trinidad's multi-faceted ecology. Essentially, the models generated in this dissertation are intended to significantly improve the cultural resource management of Trinidad's pre-Columbian sites by (a) reducing the monetary and time costs of fieldwork on the island, (b) facilitating more effective land-use management, (c) helping archaeologists to devise more appropriate field surveys strategies, (d) assisting archaeologists and cultural resource managers to create, update and protect Trinidad's archaeological database, and (e) providing an appropriate framework for developing a sustainable cultural tourism product for Trinidad.

# CHAPTER 1
# INTRODUCTION

## Research Goals

On the basis of geographical information systems (GIS), this dissertation has developed predictive models of pre-Columbian settlement sites in selected watersheds in Trinidad (250 BC to AD 900). These models are designed to facilitate more cost-effective and efficient cultural resource management of the island's prehistoric sites. Cultural resource management can be broadly defined as the conservation and carefully planned investigation of archaeological materials generally through legislation and applied archaeology (Thomas 1999).

According to Drewett (1999) cultural resource management (CRM) is a catch-all term coined in America to cover all aspects of the management of cultural resources. Also referred to as archaeological conservation and archaeological heritage management (Cleere 1989:1), cultural resource management involves the documentation, assessment, management, and sometimes excavation or conservation of irreplaceable cultural resources. These resources include heritage buildings, prehistoric sites, and even landscapes deemed significant to the public and other communities including historians, architects, and archaeologists.

## History of CRM in Trinidad

On a global scale, the end of the World War II saw the beginnings of archaeological heritage management as an integral component of social and economic

planning. The devastation of 1939-1945 provided boundless scope for archaeological initiatives in many countries (Cleere 1989:2). Excavations took place in many of the war-torn cities of Europe, of which the work on Roman Cologne around the Dom is probably the most outstanding. Postwar reconstruction was followed by the worldwide economic boom of the later 1950s and 1960s. Cleere (1989:2) posits that this was accompanied by the coming to nationhood of many colonial territories in Africa, Asia and the Caribbean. The development pressures of the 1960s and the environmental movement of the 1970s had a profound effect on cultural resource management. It is significant that almost every European country enacted new antiquities legislation during the 1970s, to replace the outdated and ineffectual statutes of the less stressful pre-war era (Cleere 1989:4). By 1981, the annual spending for CRM in the United States was estimated to be about $300 million, involving 2,000 full-time CRM staff in the federal and state agencies, with another 250 academic and non-profit institutions and 500 private firms, employing perhaps 4,000 full-time staff, providing CRM services on the contract basis (Thomas 1999:332). However, these CRM trends in industrialized countries have not been characteristic of Trinidad. Essentially, like most developing countries, archaeological heritage management has been a recent development on the island.

Despite the presence of the Royal Victoria Institute (founded in the 1880s), which showcased in its museum an assortment of pre-Columbian archaeological collections as well as the now defunct Trinidad and Tobago Historical Society of the 1950s and 1960s, the first solid attempt at CRM came with the creation of the Archaeological Committee in 1979. Comprised of approximately 8 members, with representation from the tourism industry, the Town and Country Planning Department, the Forestry Department,

Archaeology Center (UWI) and the Tobago Museum, the Archaeological Committee is appointed by the Government of Trinidad and Tobago and renders advice on archaeological and related matters to the Minister of Culture. The Committee also vets all requests for archaeological surveys and excavations to be conducted in the Twin Island Republic and monitors the work of both local and expatriate archaeologists with a view to ensuring that archaeological research projects are carried out expeditiously and effectively in the national interest.

Although the first agitation to create a National (Heritage) Trust of Trinidad and Tobago came in 1972, the National Trust Act became a reality only as recently as 1991. According to Act No. 11 (5) of 1991, the National Trust was established for the purpose of carrying out the following functions:

1. Listing and acquiring property of interest as the Trust considers appropriate;

2. Preserving, maintaining, repairing and servicing or, arranging for the preservation of property of interest other than land and where such property of interest comprises buildings, augmenting the amenities of such buildings and their surroundings;

3. Making provision for the access to and enjoyment of property of interest by the public;

4. Encouraging research into property of interest including, where applicable any animal, plant or marine life associated therewith;

5. Compiling photographic or architectural records of property of interest;

6. Making the public aware of the value and beauty of the heritage of Trinidad and Tobago; and

7. Advising the Government on the conservation and preservation and preservation of property of interest and on all matters referred to above.

In sum, although the Archaeological Committee assumes primarily responsibility for monitoring archaeological activity in Trinidad, the National Trust is currently the

chief governmental agency responsible for setting CRM policy for the entire island. The archaeological site inventory, spearheaded by Arie Boomert and Peter Harris in the 1980s, was also an important development in Trinidad's CRM, as it furnished a corpus of valuable information about the specific locations and cultural periods of the islands' pre-Columbian sites, particularly those in north, south and southeast Trinidad (Boomert 2000).

Pre-Columbian settlement sites in Trinidad, ranging from Ortoiroid (Archaic), Saladoid, Saladoid/Barrancoid to Guayabitoid, are invariably represented by middens. Identified and mapped by several avocational and professional archaeologists in Trinidad from the 19$^{th}$ century to the present, many of these sites have been either threatened or partially destroyed by urbanization, agriculture and mining (see Landell Mills Limited 1992). It is also likely that there are several additional pre-Columbian sites yet to be discovered. As it requires considerable logistical planning and staff support sometimes over an extended period of time, locating new sites can be both time-consuming and expensive. Frequent site inaccessibility and poor ground visibility (Zeidler 1995)—common to the neotropics—also serve to significantly increase time, labor and equipment costs of site location efforts in Trinidad. By providing GIS predictive models of archaeological sensitive areas, this study presents a viable option for a more cost-effective cultural resource management of Trinidad's pre-Columbian archaeological sites. Essentially, these predictive models will provide land managers with expected distributions of resources they are charged with protecting and it will furnish planners with preliminary guides to the places where archaeological sites are least likely to be affected by future construction projects (see Warren 1990:202).

The central research questions addressed by this dissertation are

(1) What is the weighted value of landform, relief, soil texture and land capability in pre-Columbian settlement location in the selected watersheds?

(2) Does the weighted value of the various environmental features vary among the watersheds and if so what are the possible reasons for such variability?

(3) How useful are these predictive models to the cultural resource management of pre-Columbian sites in Trinidad?

**Weights of Evidence**

The GIS technique of weights of evidence forms the basis upon which these GIS-based predictive models are predicated. Weights of evidence is a Bayesian approach for combining data to predict occurrence of events. It is based on the presence and absence of a characteristic or pattern and the occurrence of an event (Bonham-Carter 1994). The method was originally developed for a non-spatial application in medical diagnosis, in which the evidence consisted of a set of symptoms and the hypothesis was of the type "this patient has disease x." For each symptom, a pair of weights was calculated, one for presence of the symptom, one for absence of the symptom (Bonham-Carter et al. 1988). The magnitude of the weights depended on the measured association between the symptom and the pattern of disease in a large group of patients. The weights could then be used to estimate the probability that a new patient would get the disease, based on the presence or absence of symptoms (Bonham-Carter et al. 1988).

In spatial analysis, it has been used extensively in the mineral and mining fields but only recently has been applied to archaeological research (see Hansen 2002). For a particular spatial pattern or characteristic, weights are calculated based on

(1) The probability of the known characteristic being present with events

(2) The probability of the known characteristic being present without events

(3) The probability of the known characteristic being absent with events

(4) The probability of the known characteristic being absent without events.

These ratios are used to calculate a positive weight and negative weight for the characteristic. Since these are in log form, weights can be added to produce a contrast value for the characteristic.

The process used in weights of evidence modeling essentially is a quantitative version of the inspection method of overlaying several different maps themes to identify areas where archaeological sites may be present. In weights of evidence modeling, the importance of theme layers in delineating areas with potential for deposits is determined mathematically by how it compares with the areal distribution of the training set. For archaeological sites, weights for a theme attribute such as a geology map unit can be calculated based on the presence or absence of sites in the geological units. Weights calculated individually for several themes can be combined to produce a probability estimate or surface. When several themes are combined, the areas with the greatest coincidence of weights produce the greatest probability of occurrence of undiscovered archaeological sites (Boleneus et al. 2002:9). Combining the weights of evidences of the different predictor maps requires an assumption that the input maps are conditionally independent. Similar to the methods of multiple regression in statistics, the weights of evidence model for combining evidence involves the estimation of response variable (favorability for archaeological sites) and a set of predictor variables (exploration data sets in map form). A glossary of terms often associated with weights of evidence is in the Appendix.

## Regions of Interest

As environmentally circumscribed areas, four watersheds in Trinidad were considered ideal regions of interest for weights of evidence application (Figure 1-1). Comprised of 438 $km^2$, South Oropouche is the largest watershed followed by Pilote with 193 $km^2$. Restnorth covers an area of 81 $km^2$ and Cipero is the smallest with an area of 50 $km^2$. The four watersheds are situated in the south and southwest of Trinidad, in areas with the heaviest concentration of known pre-Columbian sites (Figure 1-2) (see Boomert 2000). Therefore, these watersheds were purposively selected in order to provide this dissertation with enough training points for the creation of relatively robust predictive models.

## Organization

The structure of this dissertation is framed within the context of Trinidad's environment. Chapter 2, which provides details about the natural environment of the island, is therefore a necessary backdrop. The chapter examines a welter of issues ranging from geographical setting, geology, soils and land capability, drainage systems, climate, flora, and faunae as well as coastal and marine environments.

Chapter 3 focuses on the pre-Columbian archaeology of Trinidad, which is conveniently divided into two sections. The first section relates to the history of archaeological research in Trinidad from the 19th century to the present while the second section details the current state of knowledge on Trinidad's pre-Columbian past. Given the central role played by settlement archaeology and geographic information systems in this dissertation, Chapter 4 examines several theoretical and practical issues related to

settlement patterns, and geographic information systems coupled with the use and misuse of GIS predictive models in settlement archaeology.

The digital data sets and the step-by-step procedures involved in weights of evidence analysis are the subject of Chapter 5. Chapter 6 discusses the results of the analysis and provides predictive models of pre-Columbian sites within the regions of interest. Also presented in Chapter 6 are the research implications of the dissertation in relation to the cultural resource management of pre-Columbian sites in Trinidad. The final chapter, Chapter 7, provides a summation of the major issues addressed in this study.

## Significance

The application of GIS as an aid to archaeological data collection and interpretation constitutes an important milestone for scholarly research in Trinidad. The results of this study will be of considerable interest to the archaeological community world-wide, as it will ably demonstrate the merits of applying GIS to small Caribbean environments where there is a rich array of cultural and biophysical features within a limited geographical area. In addition, this study represents the first attempt to clearly identify archaeologically sensitive areas on the island on the basis of GIS weights of evidence predictive models.

Due to its geographical position, Trinidad is often considered to have played a crucial role as one of the first stepping-stones in the movement of pre-Columbian peoples from the mainland of South America to the Antillean archipelago, a process that, according to radiocarbon evidence, commenced around 5000 B.C. (see Keegan 1994). Therefore, insights into prehistoric settlement patterns in Trinidad, through the application of GIS, will enhance our understanding of the relationships between the

physical environment and the settlement patterns of early pre-ceramic and Ceramic-age societies in northeastern South America and the insular Caribbean.

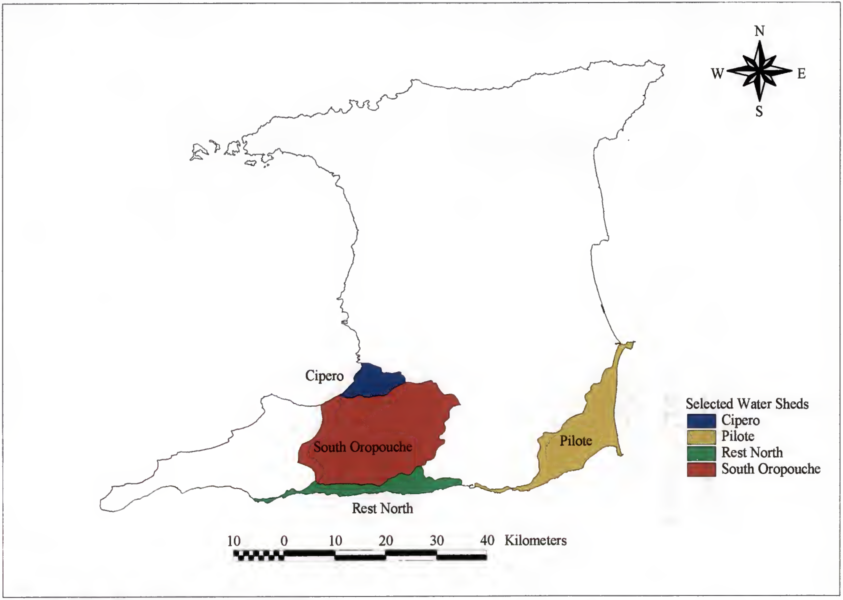


Figure 1-1 Map of Trinidad depicting Selected Watersheds

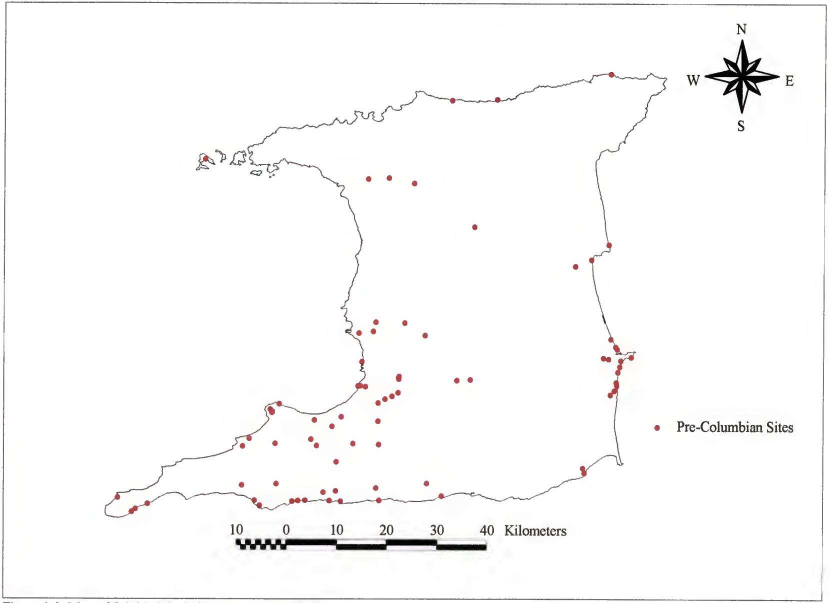


Figure 1-2 Map of Trinidad depicting Pre-Columbian Sites

CHAPTER 2
THE NATURAL ENVIRONMENT OF TRINIDAD

Trinidad is the southernmost island of the Caribbean archipelago and is situated some 18-km off the north-east coast of South America (Figure 2-1). It lies between 616,676 E; 1,110,974 N and 720,340 E; 1,199,306 N (UTM 20N Naparima 1955). The nearest Caribbean islands are Tobago, some 42-km northeast of Trinidad and Grenada, which is situated ca. 144 km away. With an area of 4,828 km², Trinidad is the sixth largest island in the West Indies, and almost as large as all the Lesser Antilles combined (Keegan 1994).

The west coast of Trinidad faces the Gulf of Paria, a calm sea with its average depth being 20-m. Trinidad is connected to the Caribbean sea in the north by a narrow outlet called Dragon's Mouth, and its southern passage, the Serpent's Mouth, joins the Gulf of Paria with the Atlantic waterway of Boca Grande (Dorst 2000:7). The smaller promontories on the eastern side of Trinidad are called Galera Point in the north and the southern tip is named Point Galeota.

**Geology**

Trinidad, or *Cairi* (*Caeri, Acaera*) as it was called in Amerindian times[1] is more or less rectangular in shape, with large promontories at its northwest and southwest corners

[1] The Arawak (Lokono) variant, *Cairi*, was first recorded by Raleigh (1848:4) in 1596. *Cairi* represents a generic term, meaning "island," an expression still being used by the Arawaks of the Guyana coastal zone in the latter part of the nineteenth century as the name for Trinidad (Brinton 1871; Laurence 1967; Lovén 1935; Taylor 1977; Wise 1934). In his *History of the World* (cited by Wise 1934/1938), Raleigh notes "Caeri, which signifieth an island." The Taino cognate, *cayo* (*cay, key*), can be recognized in *Lucayos*, the name given by the Tainos to the Indians of the Bahamas (see Boomert 2000:17). The Island Carib name of

(specifically the Chaguaramas and Cedros Peninsulas respectively, the tips of which stretch towards the South American mainland (Boomert 2000:17). Although not a large island, Trinidad has a remarkably varied geological make-up, both as to the variety of rock-types, and the structural complexity in which these are associated (Barr 1981:14). According to Barr (1981:15-16), Trinidad can be divided into the following structural groupings.

**The Northern Range**

Trinidad's Northern Range rises steeply from both the Caroni Basin and the north coast, reaching an elevation of about 940-m at Cerro del Aripo. Comprised of the oldest rocks in Trinidad of the Upper Jurassic and Cretaceous period, the Northern Range forms the eastern extremity of the eastern branch of the Andean mountain chain. This chain springs from the Columbian Andes, runs through northern Venezuela, to end in the Northern Range of Trinidad. The formations include the oldest rocks known in the island[2] (Barr 1981:15-17).

**The Northern (Caroni) Lowlands**

The Northern Lowlands overlies a broad synclinal depression, probably bounded by a large east to west fault at the foot of the Northern Range, and occupied by geologically younger formations of soft sands and clays, with superficial gravel terraces, river and swamp alluvium. To the south, the structure rises gently towards the Central Range (Barr 1981:17).

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Trinidad was recorded by Breton (1665:8, 411) as *Chaléibe* (male language) and as *acaéra* (female language), both signifying "island" similar to the Lokono form (see Boomert 2000:17).

[2] These rocks are over 170 million years old.

**The Central Range**

The Central Range is another broad anticlinal uplift, with strong folding along its central and southern margin, from Point-a-Pierre through Tabaquite, Biche, Mt. Harris and Brigand Hill. Cretaceous and Eocene rocks form the core of the structure, flanked by Miocene formations, including the prominent limestone hills such as Mayo, Biche, Tamana and Brigand Hill. The rolling country of Naparima, including the Nariva Swamp, forms the southern shoulder of this uplift, with strongly folded and faulted formations (Barr 1981:17).

**The Southern Lowlands**

Trinidad's Southern Lowlands represent a broad syncline filled with Miocene and Pliocene sands, clays and gravels, stretching from the Cedros Peninsula to Mayaro and Cocal (Boomert 2000:28). The rolling and partly low-lying areas of Erin, Oropouche and Otoire, overlie another broad synclinal trend, extending from Irois Bay to Mayaro. Generally, soft sands and clays are predominant formations (Barr 1981:17).

The highly folded and faulted Cretaceous and Tertiary deposits of south Trinidad contain numerous deposits of petroleum and natural gas of which the former has been exploited since the late nineteenth century. Natural seepages of crude oil from these underground reservoirs through fissures and cracks leading to the surface ("oil sands") are to be found on various locations in the Southern Lowlands and the Southern Range, notably on the Cedros Peninsula (Barr 1981). Seepages of asphalt from underground reservoirs form a distinctive geological phenomenon on the island. The most extended asphalt flow in Trinidad, the Pitch Lake, forms a more or less circular depression of about 600-m in diameter (Boomert 2000:28).

**The Southern Range**

Trinidad's third anticlinal trend, the Southern Range, consists of a chain of hills, situated generally below 150-m above MSL, stretching from the south coast from Palo Seco to Mayaro and Galeota Point (Boomert 2000:29). In fact, the Southern Range is formed by a series of smaller anticlinal folds separated by complicated fault systems. This fragmentation is reflected in a very diversified topography ranging from gently rolling to deeply dissected, rugged hills with locally precipitous slopes. The structure is made up of sandstones, siltstones, shales and clays deposited in Miocene times. It was formed due to geological uplift during the Pleistocene (Boomert 2000:29). Numerous seasonal streams drain the Southern Range with the Moruga River constituting the only perennial stream of the region. The Trinity Hill, with a maximum height of 305 m above MSL, represents the most elevated portion of the Southern Range. Oil sands and mud volcanoes are especially numerous in the Trinity Hills area (Boomert 2000:29).

## Soils[3] and Land Capability

Hardy (1981:27) broadly classifies the soil types of Trinidad as those of Northern (i.e., the Northern Range), Central and Southern Trinidad. Table 2-1 provides information on soil types in Central Trinidad. The land relief of the Northern Range is

[3] The soils of Trinidad have been systematically studied since 1926 by the Soils Departments of the Imperial College of Tropical Agriculture and the Trinidad Department of Agriculture. The investigations culminated in the publication in 1952 of a monograph entitled "The Soils of Central Trinidad," by Dr. E.M. Chernery, Government Soil Surveyor, who mapped the soils of this part of the island during the years 1936 to 1939. Many different ways of classifying soils have been devised, depending in what particular aspect is being stressed. In the following account, the classification system elaborated by Chernery is used, as it is essentially practical (Hardy 1981:23). In Chernery's scheme, differentiation is first made on the basis of *land relief*, which is sub-divided into flat, rolling, undulating and steep. Next, differentiation is made on *internal drainage*, which is subdivided into excessive, free, imperfect and impeded. Further differentiation, which is used to define soil units, is made on *lime content*, with which organic matter content, nutrient status, and soil permeability, are closely associated. Lime content depends on the kind of rock upon which soil develops, through the operation of the climatic and biotic factors of soil formation (Hardy 1981:23). Since the publication of Chernery's account of soils in Central Trinidad in 1952 the rest of the island has been surveyed by G. Witt, who succeeded E.M. Chernery as Government Soil Surveyor (Hardy 1981:27).

comprised of (a) high flood plains or River Vegas and (b) steep land of the foothills and mountains rising to a little over 3,000 feet. The northern slopes are precipitous. The foothills forming in the southern flank of the range are cut through by south-flowing rivers which have wide interior basins, partly filled with alluvium. According to Hardy (1981:27) a single free-draining soil type (No. 25 River Estate Series) is developed in the alluvium. The remaining soil types, occurring on sloping land, are all free-draining sand, loams, and loamy-clays, developed on fine-grained metamorphic sediments, limestone, and sub-basic igneous rock (Hardy 1981:27). Most soils in the Northern Range have little agricultural potential. The mountain slopes are characterized by acid, poorly drained soils and weathered ultisols (e.g., Hardy 1981; Norman et al. 1984:61-63; Weir 1980:93). Soils better suited to agricultural purposes are less widely distributed. Moderately fertile alfisols are to be found in the valley interiors and along the shores of the Atlantic in the Toco area of the northeast (Boomert 2000:26).

As depicted in Table 2-1, the soil types of Central Trinidad are generally classified as soils of flat land, intermediate flood plains, high flood plains, undulating land, rolling land and steep land. These soil types have a variety of drainage levels ranging from excessive drainage (soil types 11, 40, 51-53) to impeded drainage (soil types 22-23, 38-39, 47-50) (Chernery 1952; Chernery and Hardy 1945).

Southern Trinidad consists of four distinct areas, (a) Southern Range, less than 800 feet in elevation, (b) Cedros Peninsula (c) Oropouche Lagoon and (d) Moruga River Basin (Hardy 1981:27). The first two areas comprise rolling land occupied by three of the same soil types, having imperfect or impeded drainage, that occur also in Central

Trinidad (namely, Nos. 49, 50,59). The last two areas comprise low flood plains and are occupied by five soil types, which are heavy swamp clays (Nos. 71-5) (Hardy 1981:27).

Land capability is defined as the capacity of land for producing crops (Hardy 1974:55). The Land Capability Survey of Trinidad was begun in 1963, as a continuation of the soil survey of central Trinidad carried out by E.M. Chernery in 1937-1948. It was sponsored jointly by the Government of Trinidad and Tobago, the University of the West Indies, Texaco, Shell, British Petroleum, Tate and Lyle (Hardy 1981:37). The seven land capability classes for Trinidad have since been updated by the Ministry of Food Production and Marine Resources and are summarized in Table 2-2.

## Drainage System

In general terms, the main drainage of Trinidad involves six major river systems: the Caroni, Oropouche (northern), Guaracare, Nariva, Oropouche (southern) and Ortoire. In addition, many smaller streams drain the remaining areas, such as the north flank of the Northern Range and the southern slopes of the Southern Range (Barr 1981:18).

The northern drainage area of Caroni and the northern Oropouche is characterized by mature systems of broad alluvial-filled valleys and meander belts in the lower reaches. Both rivers, particularly the Caroni, have extensive swamps at the mouths, which in the case of the Caroni River is a tidal mangrove swamp (Barr 1981:18). The Caroni originates as the Aripo River in the Northern Range and drains about two-thirds of the Northern Basin (Boomert 2000:26). In the times of sailing craft it was considered to be navigable for 28-km upriver though only its lower course was formerly used to transport cane sugar in flat boats to the Gulf of Paria (Joseph 1838:20). The Caroni mouth is shoaly with mud flats and a sand bank, which are passable only at low tide (Boomert 2000:27).

These northern lowlands have evidently been a low-lying area for a relatively long period, as the whole area is characterized by several river terraces at varying levels, above the present alluvial flats (Barr 1981:18). These give rise to the widespread plains and "savannas," and also to the higher-level benches and beveled platforms on the foothills of both the Northern and Central Ranges. These level terrace deposits are generally very porous, and because of the resulting high degree of leaching, produce very impoverished soils (Barr 1981:18). It may also be noted that these river terrace relics are evidence of a relatively recent elevation of the land surface, as a result of which the river systems have cut down through their pre-existing flooding plain. Contrariwise, the presence of tidal swamps at the river mouths implies a slight submergence, with consequent rise in sea level (Barr 1981:18).

The major river systems of the south exhibit somewhat similar features but to a less marked degree, and especially notable is the absence of the wide terrace and flood plain topography, so characteristic of the northern lowlands. The Nariva and Oropouche swamps are somewhat similar to the northern swamps, and both have tidal salt marsh and mangrove conditions at the coast (Barr 1981:18). The Oropouche lagoon has been partially drained and cultivated, whereas the Nariva swamp is virtually undisturbed and contains extensive herb marshes and other interesting floral associations. The Ortoire river system, the most vigorous of the south, has no associated swamp (Barr 1981:19).

**Climate**

Trinidad has an overall humid tropical seasonal climate with only small local variations on the island due to physiographic features (Dorst 2000:10). According to Berridge (1981:3) Trinidad's major climatic controls are as follows: (a) latitude, (b)

oceans, (c) landmass size, (d) the Bermuda/Azores anticyclone, (e) air mass migrations and (f) topography. The seasonal variation of the island fluctuates mainly between the dry and wet, the former coinciding for the most part with the Northern Hemisphere winter, and the latter with the summer[4] (Berridge 1981:3).

The dry season (from January to May) is noticeably bright and sunny, with few small cumulus clouds and lower relative humidities, the latter offering more acceptable human comfort levels. Temperatures during the dry season vary from a maximum of 32°C in April and a minimum temperature of 20°C in January (Dorst 2000:10). On rare occasions, considerably modified zone weather systems reach the region, with some cloudiness, and even persistent precipitation may occur. For the most part, however, precipitation is minimal during this time of the year (Berridge 1981:3). During the wet season, tropical weather systems, including the Intertropical Convergence Zone (I.T.C.Z.) (broadly speaking this is the confluence of NE and SE Trades), Easterly Waves and tropical depressions, develop in the deep Easterly air mass, with attendant cloudiness and precipitation, and consecutive bright and sunny days are at a minimum (Berridge 1981:3).

In spite of the small size of the island, there are significant differences spatially in the annual rainfall amounts, decreasing westwards, as well as variations in diurnal distributions. The topography of the Trinidad land mass, with its Northern Range as the major mountain systems serving as the orographic spring-board for lifting air masses approaching the island, and the dominant East, North-easterly trades, give the NE quadrant of the island the areal maximum. Trinidad's annual rainfall totals vary from

[4] Location in the tropics (latitude) ensures direct solar radiation, which in turn, is tempered by small land mass size in a large ocean space, with sea breezes being dominant, and resulting in minimal seasonal variations (Berridge 1981:3).

over 120" (3048 mm) in the NE to approximately 60" (1524 mm) in the NW and SW peninsulas of the island, and are indicative of the role of topography and upwind location in the local precipitation regime (Berridge 1981:4). The difference in amounts between the wet and dry seasons is large, with wet season maps showing a distribution from 80" (2032 mm) to 25" (635 mm) and dry season from 40" (1016 mm) to 10" (254 mm) (Berridge 1991:4).

Ocean effects on a small island mass located on the tropics dictate relatively minor seasonal variations of "dry-bulb" temperatures. Mean annual surface temperature is fairly constant at about 25.5°C; its monthly oscillation is at most 2-3°C (Boomert 2000:23). Diurnally the variations are greater, amounting to approximately 10-15°C between night and day (Berridge 1981:8). Trinidad is situated at the southern fringe of the Caribbean hurricane zone and as such these destructive tropical storms pass over the island very infrequently (Boomert 2000:23).

### Flora

Trinidad was connected to the mainland until the end of the Pleistocene, so it has a more continental flora and fauna (Keegan 1994). According to Beard (1946:36) the plant communities in Trinidad can be classified as follows:

*Climatic*

1. Seasonal Formations
2. Dry Evergreen Formations
3. Montane Formations
4. Intermediate Formation

*Edaphic*

5. Swamp Formations
6. Marsh Formations

Every formation expresses a habitat determined by the interplay of the environmental factors of climate, topography and soil. Formations are said to be climatic when climate is of greater preponderance, and edaphic when topographical and soil factors exert a predominant influence. There is no satisfactory distinction between these two groups, which are arbitrary and made for convenience (Beard 1946:36).

The great bulk of the forests of Trinidad are seasonal types. They vary from evergreen to deciduous according to the available moisture and compose almost the whole of the remaining forests in the lowland center and south of the island. Examples include *Licania biglandulosa, Pentaclethra macroloba, Pentaclethra macroloba, Mora excelsa, Peltogyne-Eschweilera, Trichilia-Brosimum* and *Bursera-Lonchocarpus*. Seasonal forests are absent from the northern mountains and give way to marsh and swamp trees in areas of very flat or depressed topography or to littoral woodlands along the coast (Beard 1946:37). Littoral woodland comprised of *Coccoloba uvifera-Hippmane mancinella* and *Roystonea oleracea-Manikara bidentata* falls under the rubric of Dry Evergreen Formation. Littoral woodland is confined to the north and east coasts and is a special climatic type under the influence of the trade wind driving in from the sea carrying a fine salt spray which is deposited on the plants (Beard 1946:40).

Trinidad possesses a range of mountains running from east to west across the north of the island. The average elevation of its main ridge is about 2,000 ft., but several peaks exceed this, notably El Tuchuche, 3,2072 ft., and El Aripo, 3,085 ft. Above 2,500 ft. lies the zone of montane rain forest, characterized by poverty of tree flora, great luxuriance of epiphytes, low open structure, and the presence of large tree-ferns (Beard 1946:40). The characteristic flora of montane rain forest is *Richeria grandis-Eschweilera* sp. At the

summit of Aripo above 2,900 ft is situated a montane formation termed Elfin or Mossy Woodland. A thicket rather than a forest, it is characterized by short, often gnarled or oblique stems and long serpentine branches (Beard 1946:41). *Clusia intertexta* is a dominant plant life in the Elfin Woodland.

The Intermediate Formation describes a type of forest in the Northern Range which is intermediate in character between seasonal and montane forests and which is of too great importance to be disregarded as an ecotone. It is therefore named Seasonal Montane Forest and classified as intermediate (Beard 1946:43). This type occurs on limestones between 1,000 and 2,000 ft. elevation. Soil, however, is often non-existent. In the mountains rainfall shows seasonal fluctuations, but is sufficient in amount to sustain growth during the dry season wherever there is soil to retain moisture. Here, however, subsoil drainage is so free that seasonal droughts are often precipitated by the lack of moisture in the area. *Inga macrophylla-Guarea guara* is the principal flora of the Intermediate Formation (Beard 1946:43).

There are three large areas of swamp[5] in Trinidad on low-lying areas near the coasts, the principal being the Nariva and Caroni swamps and the Oropouche, Los Blanquizales, Roussillac, and Icacos logoons. In the Nariva Swamp the principal components are *Cyperus giganteus, Gynerium sagittatum, Montrichardia arborescens,* and a tall grass called "water bamboo." Where there is considerable human interference, as in the Caroni and Roussillac swamps, smaller Cyperaceae cover large areas. The fern

[5] Beard (1946:43) makes a distinction between swamps and marshes. In his view, a swamp may be defined as an area, usually of depressed topography, where owing to difficulties of external drainage the soil is inundated for the whole or a large part of the year. A marsh, on the other hand, may be defined as an area of flat topography, not necessarily depressed, where, for reasons such as the presence of iron-pan, clay-pan, or impermeable subsoil, internal soil drainage conditions are extremely bad and there is a seasonal alternation of water logging and desiccation. In short, a swamp is always full of water, but a marsh is only seasonally so (Beard 1946:43).

*Acrostichum aureum* represents a transition to mangrove conditions (Beard 1946:44). "Marshes" are of local occurrence and occupy the centers of the Pleistocene alluvial terraces, mainly in the Northern Plain. The marsh savannas of Aripo, for example, are characterized by *Byrsonima crassifloia-Chrysobalanus pellocarpus*. The flora of "palm marshes" (which usually thrive on flats with impermeable subsoil) frequently consists of *Mauritia-Chrysobalanus* (Beard 1946:45).

## Faunae

Trinidad's faunae occupy three major ecological zones: the tropical rain forests, swamp and mangrove areas and the seas (Atlantic ocean and Caribbean sea) and seashores[6] (Dorst 2000:12). The tropical rainforests (including swamp forests) of Trinidad are inhabited by various species of mammals, reptiles and birds, many of which were unrelentingly hunted by pre-Columbian peoples. The upper story of tropical rain forests, for example, by the three-toed anteater *(Tamandua)*, prehensile-tailed porcupine (*Coendu prehensilis*), red howler monkey (*Alouatta seniculus*), capuchin monkey (*Cebus albifrons*), tayra (*Eira barbara*), ocelot (*Felis pardalis*), squirrels (*Sciurus granatensis*) and various species of opposum (Alkins 1979: Bacon 1978:61-77). The tiny hummingbirds (Trochilidae) belong to the most conspicuous inhabitants of the forest's lower story. The forest floor is the domain of herbivorous mammals such as the red brocket (*Mazama americana*), agouti (*Dasyprocta aguti*) and paca *(Agouti paca)* (Boomert 2000:33). The largest mammal of the Trinidad forest in pre-Columbian times, the tapir (*Tapirus terrestris*), became extinct in the nineteenth century (Alkins and De Souza 1983; Wing 1962:64,71). Also occupying the forest floor are the black-eared opossum (*Didelphis marsupialis*) and the woolly oppussum (*Caluromys philander*)

(Ramdial & Ramdial n.d. 1). There is a progressive decrease in animal life as the forest environment moves away from the optimal conditions of the evergreen seasonal or lower montane forest (Bacon 1978:79).

The richest animal biomass in Trinidad belongs to swamps and rivers (Boomert 2000:35). Typical freshwater swamp dwellers include crab-eating raccoons (*Procyon cancrivorus*), otters *(Lutra enudris)* and water rats (*Nectomys squamipes*). Capybaras (*Hydrochaeris hydrochaeris*), now extinct in Trinidad, once occupied various river and swamp environments on the island. Other prominent inhabitants of the swamp habitat are the freshwater turtle (*Geomyda sclerops*), the anaconda (*Boa constrictor*) and the spectacled caiman (*Caiman sclerops*) (Bacon 1978). Freshwater to brackish swamp fish include mullet (*Mugil* sp.), snook (*Centropmus* sp.) and various species of catfish (Ariidae). The humid edges of swamps form the habitat of numerous land crabs such as the blue crab (*Cardinoma guanhumi*) and hairy (*Ucides cordatus*).

## Coastal Environment

Physiographically, Trinidad's four shores are quite different from one other. The east coast is comprised of small sand beaches alternating with rocky cliffs and points where the Northern Range reaches the shore, to the south where there are long stretches of sand beach. All along the east coast the sea is rough due to the trade winds and its beaches are constantly pounded by the Atlantic sea (Boomert 2000:29).

In contrast, Trinidad's south coast is characterized by slight points, relatively few sheltered bays with beaches together with vertical, whitish cliffs which inspired seventeenth-century Spaniards to name it the *Costa se los Blanquizales* (Tatton 1628?). Erin and Guayaguayare are the only south coast bays sufficiently protected from the trade

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[6] Marine faunae will be discussed in the section in this chapter dealing with "Marine Environment."

winds although in the wet season landing remains difficult in these areas (De Verteuill 1884:43).

The west is lined with bays forming safe natural harbors of which the Naparima Bay is the largest (Borde 1982). Erosion predominates north of the La Brea promontory while the southwest end of the Cedros Peninsula is accreting, forming the underwater Saldado platform (Boomert 2000:30). Off the west coast the sea bottom is generally smooth. In the Gulf of Paria, the substratum consists of fine mud and occasionally sands and shells (Van Andel & Postma 1954:18-24).

The north coast is the least accessible. Here the Northern Range rises steeply form the sea floor. Not only is a coastal plain totally lacking on the north coast but the shore is rocky and fringed with coral reefs, showing only a few sand beaches (Boomert 2000:30). Moreover, due to the trade winds the surf is often tumultuous to the point of making landing almost impossible. Maracas Bay forms the only sufficiently protected natural harbor (De Verteuil 1884).

## Marine Environment

As Trinidad is influenced by the river discharge from South America, its water characteristics are extremely varied. There is first of all a marked seasonal variability in salinity, tied to seasonal changes in the Guyana Current and outflow from the Orinoco (Kenny and Bacon 1981:115). In the wet season the huge amount of freshwater discharged by the Orinoco reinforces both a northerly-directed stream along Trinidad's east coast and the currents with high velocity passing through the Columbus Channel (Boomert 2000:19). The outflow of muddy, yellowish-brown water and the discharge of mainland rivers such as the Río San Juan and Río Guanipa reduce the salinity of the

surface water in the Gulf of Paria to such a degree that throughout the wet season its condition approaches that of freshwater, whereas it is near-oceanic in character during the dry season (De Hostos 1941:37; Kenny and Bacon 1981; Van Andel 1967; Van Andel and Postma 1954:172-173). The wet-season fresh-water corridor between the mainland and Trinidad facilitates the survival of animals such as caimans, lizards, and fish species with low salt tolerance that drift with the current from the Orinoco Delta to the south Trinidad (Atkins & De Souza 1983).

Trinidad has an extensive continental shelf along both its north and east coasts, shallow basins in the Gulf of Paria as well as along its south coast. This sea bottom, being more productive than other parts of the region, is amenable to the development of both pelagic and demersal fisheries (Kenny and Bacon 1981:115). Kenny and Bacon (1981:118) estimate that the marine community of more than 300 species. Most of the commercially important species fall into two important orders, the Clupeiformes, the herring-like fishes, and the Perciformes, or perch-like fishes. Each of these orders has several families, and in the case of the former, the locally important families are the Clupeidae (herrings, sardines) and the Engraulidae (anchovies, joshua). Apart from the above, which are all bony fishes, there is also that other group of marine vertebrates referred to as the cartilaginous fishes or elasmobranchs. This group includes the sharks and rays (Kenny and Bacon 1981:119). A number of crustacea are exploited in coastal waters of Trinidad, as well as in more distant continental shelf areas. The main groups include the shrimp (*Penaeus brasiliensis* [red spotted shrimp], *P. notialis* [pink shrimp], *P. schmitti* [white shrimp]), lobsters for example *Panulirus argus* and *P. laevicaudus* and crabs *Callinecies* and *Grapsus*. Five types of sea turtles have been found nestling on

north and east coast beaches of Trinidad. Estimates of population sizes are available only for the leatherback (Bacon 1978) with 400-500 mature females visiting Trinidad's beaches (Kenny and Bacon 1981:129). The coastal regions of Trinidad are rich in mollusks, nearly 200 species being readily collected in intertidal and shallow, subtidal waters. Prime examples include *Chiton marmaratus, C. tuberculatus, Acanthopleura granulata, Strombus gigas, Melongena melongena, Perna perna, Donax dentiulatus, D. striatus, Isognomon alatus* (Kenny and Bacon 1981:128).

## Conclusion

Clearly, the pre-Columbian peoples of Trinidad were offered a rich food supply from a variety of microenvironments. These microenvironments ranged from mangroves, swamps, rivers, and forests to marine and coastal areas. The mild tropical climate, characterized primarily by wet and dry seasons, coupled with arable land in the central and south of the conceivably encouraged horticultural activity. These environmental descriptions of Trinidad are contemporary and therefore with the exception of geology and geomorphology, may not be entirely applicable to the island prior to the arrival of Columbus in 1498. Despite this, they suggest that Trinidad was generally considered favorable for settlement positioning and this no doubt encouraged several Amerindian groups to migrate from north-east South America and extensively occupy the island from 5000 BC to 1498 (see Boomert 2000; Keegan 1994). This abundance of pre-Columbian sites in Trinidad underscores the necessity of GIS-based predictive models, which will serve to foster more effective cultural resource management (CRM) of the country's archaeological heritage.


Figure 2-1. Map showing Trinidad's location in the Caribbean region. (Source: *Manzanilla 1: An Archaeological Survey of A Pre-Columbian Site in Trinidad* by Marc Dorst; Leiden University, 2000).

Table 2-1. The Soil Types of Central Trinidad.

| | |
|---|---|
| (A) *Soils of Flat Land* | |
| 1. *Low Flood Plains (Swamps; elevation* −3 to +25 ft.) | |
| Impeded drainage | Soil types *1–10* |
| 2. Intermediate Flood Plains (Vegas; elevation 2 to 50 ft.) | |
| Excessive drainage | Soil types *11* |
| Free drainage | Soil types *12–14* |
| Imperfect drainage | Soil types *15–21* |
| Impeded drainage | Soil types *22–23* |
| 3. High Flood Plains (Broad flats; elevation 25 to 75 ft.) | |
| Free drainage | Soil types *24–28* |
| Imperfect drainage | Soil types *29–32* |
| (B) *Soils of Undulating Land* | |
| 4. Detrital Terraces (Base of Northern Range; elevation 50 to 125 ft.) | |
| Imperfect drainage | Soil types *33–37* |
| Impeded drainage | Soil types *38–39* |
| (C) *Soils of Rolling Land* | |
| 5. Low Hills (Dissected peneplains; elevation 100 to 250 ft.) | |
| Excessive drainage | Soil types *40* |
| Free drainage | Soil types *41–42* |
| Imperfect drainage | Soil types *43–46* |
| Impeded drainage | Soil types *47–50* |
| (D) *Soils of Steep Land* | |
| 6. Central Range (Mostly calcarous rocks; elevation 250 to 1000 ft.) | |
| Excessive drainage | Soil types *51–53* |
| Free drainage | Soil types *54* |
| Imperfect drainage | Soil types *55–62* |

Note. The figures on the right are the index numbers of soil types.

* The subdivision does not include the soils of the Northern Range and those of Southern Trinidad which were not included in Chenery's survey.

After E. M. Chernery (1952)

Table 2-2. Land Capability Classes for Trinidad and Tobago

| CLASS | DESCRIPTION |
|---|---|
| I | Very good land that can easily be cultivated |
| II | Very good land that can be easily cultivated, simple protective measures required. |
| III | Good land, requires moderate to intensive conservation and management practices. |
| IV | Moderately good land, requires intensive conservation and management practices. |
| V | Fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope. |
| VI | Unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest. |
| VII | Unsuitable for agriculture due to very steep slopes. Should be left under indigenous growth. |

(Source: Ministry of Food Production and Marine Resources, Trinidad and Tobago).

CHAPTER 3
THE PRE-COLUMBIAN ARCHAEOLOGY OF TRINIDAD

## The History of Archaeological Research in Trinidad

Historically, archaeological research in Trinidad has for the most part been spasmodic and descriptive. Recent efforts to create an inventory of pre-Columbian sites on the island (Boomert and Harris 1984) are commendable but this does not negate the fact that the level of archaeological research in Trinidad has woefully lagged behind that of several Caribbean islands (see Alegría 1983; Chanlatte Baik and Narganes Storde 1990; Drewett 1989, 1991; Keegan 1992, 1994, 1996, 2000; Peterson 1996; Peterson and Watters 1991; Rodríguez 1991, 1997; Rouse 1992; Siegel 1991, 1992, 1995, 1996a, 1997; Versteeg and Schinkel 1992; Watters 1994; Wilson 1997a). The existing corpus of knowledge on the island's prehistory is largely based on the work of a handful of expatriate avocational and professional archaeologists from the late 19th to the 20th centuries (Boomert 2000). Despite recent isolated attempts to address questions of evolution, social and political organization, mythology, cosmology and ideology (Boomert 2000; Harris 1991), archaeological activity in Trinidad has, for several years, been predicated on "digging 'telephone booths' in middens to get decorated potsherds to plug into Rouse's time-space systematics"[1] (see Keegan 1994:255). Therefore, with the exception of Manzanilla[2] (Dorst 2000, 2001; Dorst and Nieweg 2002), the vast majority

[1] According to Keegan (2000:139-140) most research in the West Indies is structured by Irving Rouse's methods of time-space systematics. In this system, the characteristic "modes" of pottery at a site have been used to identify a "style" that usually bears the name of the first site at which it was described. For the smaller islands, there is often only one style per time period. Local pottery styles that share sufficient

of excavations in Trinidad have little or no areal or regional component specifically as it relates to the associational distribution of artifacts, features and sites on archaeological landscapes.

The dearth of archaeological research is not restricted to Trinidad but appears to be a pervasive throughout much of lowland South America and the Caribbean (Ziedler 1995; Siegel 1995), although research efforts have been invested in particular regions and islands more than others (Chanlatte Baik and Narganes Storde 1990; Alegría 1983; Keegan 1992, 1994, 1996, 2000; Lathrap 1970, 1977; Meggers 1971, 1985; Peterson 1996; Peterson and Watters 1991; Rodríguez 1991; Roosevelt 1980, 1991, 1999; Rouse 1974, 1992; Siegel 1991, 1996; Versteeg and Schinkel 1992; Watters 1994; Wilson 1997). Stahl (1995:1) argues that the relative paucity of systematic regional and community archaeological investigation conducted throughout the lowland American tropics is generally attributed to a combination of logistical restraints, lack of ground visibility, meager preservation, and/or historic preservation of lowland environments. It would appear, though, that the situation in Trinidad has been significantly compounded by other factors such as the absence of local archaeologists working consistently in the field coupled with the non-existence of legislation for the protection and preservation of archaeological sites. Despite this, the discoveries of early antiquarians and later amateur

similarities are grouped into subseries (denoted by an –an suffix), and subseries are grouped into series (denoted by an –oid suffix). Rouse (1992:182) uses this classification to identify "peoples" and "cultures," which are "two sides of a coin, one consisting of a local population group and the other of the cultural traits that define the group." Keegan (2000:139-140) is of the view that this system has created the impression that during the ceramic age the West Indies were colonized by a single culture and that the descendants of this culture were the only ceramic age peoples to occupy the islands. Rouse (quoted by Siegel 1996b) has worked hard to maintain this impression in opposition to those who have viewed each new style as evidence for a new migration of peoples from the mainland.

[2] Manzanilla is a Saladoid/ Guayabitoid site situated on the east coast of Trinidad, immediately north of the Nariva swamp.

and professional archaeologists have not been insignificant, as they have provided important basal information about Trinidad's pre-Columbian past, particularly in relation to site locations and their associated cultural periods (Harris 1974, 1976, 1985).

According to Boomert (2000:8), the history of archaeological research in Trinidad can be broadly divided as follows:

1. The Early Period of Investigation. This period stretched from the mid-nineteenth century well into the 1910s and was characterized by an emphasis on artifactual collections and rudimentary descriptions of pre-Columbian artifacts.

2. The Intermediate Period. Spanning from the 1910s to the 1960s, this period saw the development of stratigraphic excavation and classificatory-historical approaches, which helped to establish local chronologies for the twin islands.

3. The Recent Period. This period has been characterized by the continuation of chronological studies coupled with theoretical paradigms relating to the reconstruction of past lifeways, techno-environmental adaptation and socio-cultural development.

**The Early Period**

Interest in the pre-Columbian antiquities of Trinidad and Tobago was first generated in the second half of the nineteenth century. During their geological survey of Trinidad in 1858, Wall and Sawkins encountered shell midden deposits in various parts of the island, which they interpreted as natural phenomena (Wall and Sawkins, 1860:66-67). As early as 1864 these "raised beaches" were identified as prehistoric Amerindian refuse heaps by the famous Trinidadian naturalist R.J. Lechmere Guppy. However, it was the 1888 discovery of the Erin midden by H. Fowler and the then Governor of Trinidad, Sir William Robinson that generated the most interest. This was due mainly to the attractively decorated pottery encountered at this site, which ultimately found its way to the newly established Royal Victoria Institute Museum in Port-of-Spain (Bullbrook 1960:6-7; Collens 1888; Fewkes 1907:190-191). Bullbrook (1953) cites this discovery as

the first authentic find of aboriginal remains in Trinidad. An account of this find was published, with admirable illustrations, in *A Guide to Trinidad* (Collens 1888). The ultimate fate of the collection is unknown, though it is possible that some of it was in the local museum when it was destroyed by fire in 1920 (Bullbrook 1953).

Bullbrook (1953) asserts that for the following two decades or more, the Government paid minuscule attention to the island's archaeology. All local interest in the subject seemed to have been suspended during those years, save for a few amateur collectors such as Menzies, warden of Erin and O'Connor, a cocoa planter, both of whom lived in close proximity to the Erin midden. The cream of Menzies' and O'Connor's collections (including several complete vessels) was deposited in the local museum only to be eventually destroyed by the 1920 fire.

At the turn of the 20th century, the Rev. Thomas Huckerby of San Fernando put together a substantial collection of individual archaeological finds from the Erin, Lagon Doux and St. Bernard (Mayaro) middens in Trinidad (Boomert 2000:8). This was undertaken on behalf of the Heyes Foundation, and subsequently the Museum of the American Indian, New York (Anonymous, 1922:36-37). However, Huckerby and his contemporaries made no attempt to classify and interpret these artifactual collections (Boomert 2000:8).

During the Classificatory-Descriptive Period in New World Archaeology, Jesse Walter Fewkes was the principal worker in the West Indies (Willey and Sabloff 1993:84). By extensively compiling ethnographic data on the Caribs of Arima when he first visited the island on behalf of the Museum of the American Indian in 1904, Fewkes ushered into Trinidad a new era of investigation (Boomert 2000:8). Nine years later Fewkes returned

to Trinidad under the joint aegis of the Bureau of American Ethnology and the Museum of the American Indian in order to assemble a substantial collection of archaeological finds from the Erin site, which at the time was being excavated for shells by the colony's Public Works Department[3] (Boomert 2000:8; Fewkes 1907:18, 1914, 1922:62-78).

Fewkes' research was continued by Theodore de Booy who also carried out extensive archaeological excavations on behalf of the Museum of the American Indian[4]. Neither Fewkes nor De Booy dug stratigraphically as they mixed cultural levels and interpreted all finds as evidence of "one uniform Amerindian culture" (Boomert 2000:8). Boomert (2000) argues influenced by Boasian historicism, Fewkes emphasized fieldwork and developed the first culture area model for Trinidad and the rest of the Caribbean. Moreover, he devised the first rudimentary chrono-cultural classification of the region (Boomert 2000:8-9). Fewkes saw Trinidad as an entity unto itself, distinct culturally as well as linguistically from the mainland and the other islands of the Antilles (e.g. Fewkes, 1915, 1922:58-60, 259, 266; Glazier, 1978; Watters, 1976:13-14, 28-29).

However, Bullbrook (1953:7) offers a less favorable opinion of Fewkes' and De Booy's contribution to Trinidad's archaeology, which he described as follows:

> Two small expeditions were made from the United States in 1913 and 1915 respectively, the first by J.W. Fewkes on behalf of the Smithsonian Institution, the second by T. de Booy on behalf of the Museum of the American Indian, Heyes Foundation. Each of these workers excavated entirely on private property – the former at Erin and the latter at Mayaro – and the Government had neither sponsorship nor interest. Neither of their excavations were carried out with anything approaching the scientific exactitude demanded today, and they left the study of Trinidad archaeology practically where it was previously.

[3] The shells were being used for road gravelling.

[4] These excavations were conducted between May and September 1915 at pre-Columbian middens at St. Bernard (Mayaro) and the Cocal I in southeast Trinidad. (see Boomert 2000:8-9; De Booy 1917).

**The Intermediate Period**

John A. Bullbrook (1881-1967), a local avocational archaeologist, was the first to use modern stratigraphic techniques in Trinidad (Boomert 2000:9). Arriving in Trinidad in 1913, the English-born oil geologist quickly became the pivotal force of the island's archaeological research program for close to half a century (Boomert 2000:9). After successfully halting the destruction of the Palo Seco midden by the Public Works Department, a government grant allowed Bullbrook to investigate the site from April to September 1919. All of his finds were donated to the British Museum, London (Bullbrook 1941, 1953:8, 15-17, 1960:7, 1961). Containing tremendous site details related to field methods, artifacts, midden(s) and shell remains, Bullbrook's detailed report on the Palo Seco excavations remains to this day a significant piece of work not only for its discussion of the stratigraphy of archaeological deposits but also for its emphasis on the reconstruction of prehistoric subsistence patterns (see Boomert 2000:9-10; Bullbrook 1953)[5]. Like Jesse Walter Fewkes, Bullbrook believed that Trinidad was inhabited by one distinct cultural group throughout most of its prehistory (Boomert 2000:9-10; Bullbrook, 1953:68, 90).

In 1932 Bullbrook took up residence on Trinidad's south coast, close to the Erin midden (Boomert 2000). In the early forties, this research took place under the auspices of the Archaeological Section of the Historical Society of Trinidad and Tobago. This Society was jointly established by Bullbrook, the geologist Kenneth W. Barr and Lieutenant J.E.L. Carter. For a few years, the Archaeological Section received a modest

[5] Unfortunately, Bullbrook's Palo Seco manuscript was not published until the 1950s (Boomert 2000; Bullbrook 1953).

government grant covering the expenses of the Erin work (Bullbrook, 1941, 1953:9; Espinet 1950).

During a short visit to Trinidad in 1941 Cornelius Osgood of Yale University, New Haven noticed that the Trinidadian Amerindian pottery shared many similarities with ceramics that he had previously excavated at Barrancas, just above the delta of the Orinoco River in Venezuela (Bullbrook 1953:5; Osgood, 1942; Rouse 1951). Intrigued by these stylistic similarities, Osgood subsequently encouraged another Yale scholar, Irving B. Rouse, to extend Yale University's Caribbean Archaeological Program to Trinidad in order to collaborate with Bullbrook. In July/September 1946 this resulted in extensive excavations by Rouse at five sites in southwest Trinidad, i.e. Cedros, Palo Seco, Quinam, Erin and Bontour. Carried out under the auspices of the Peabody Museum of Yale University and the Archaeological Section of the Historical Society of Trinidad and Tobago (Bullbrook 1953:5; Rouse, 1946). Rouse's work led to the first relative chronology and prehistoric cultural classification of Trinidad. He was able to distinguish four subsequent ceramic complexes in the island, the Cedros, Palo Seco, Erin and Bontour "styles," respectively, which could be correlated to various assemblages elsewhere in the Caribbean (Rouse 1947).

Rouse returned to Trinidad in order to examine two pre-ceramic middens, St. John and Ortoire, in July/ August 1953. At around the same time, John M. Goggin of the University of Florida excavated two protohistoric sites, St. Joseph 2 and Mayo (Rouse 1953, 1960:10-12). Most of the materials recovered by Rouse and Goggin in 1946 and 1953 remained unpublished. Rouse's work clearly linked Trinidad's prehistoric past to that of the mainland of South America, more specifically the Lower Orinoco Valley. The

Cedros and Palo Seco "styles" appeared to belong to the Saladoid series, i.e. the earliest pottery-making culture of the Caribbean, whereas the Erin and Bontour complexes could be assigned to the Barrancoid and Guayabitoid series, respectively (Cruxent and Rouse 1958:29-30; Rouse 1953, 1964). Quite significantly, the first radiocarbon dates for prehistoric Trinidad were obtained as a result of Rouse's work at Ortoire, on the eastern coast of Trinidad (Boomert 2000).

In 1946 and 1953 Elizabeth S. Wing of the University of Florida studied animal bone materials excavated in Trinidad (Wing 1962). This constituted the first detailed analysis of food remains apart from shells, recovered from archaeological sites in the Caribbean. In Boomert's (2000) view, this signaled the beginning of a shift in archaeological research orientation in Trinidad from exclusively culture-historical interpretation towards reconstruction of past subsistence patterns and mode of life (Boomert 2000).

In 1953 Bullbrook was appointed curator at the Royal Victoria Institute Museum, Port-of-Spain, to which he donated his entire collection. The museum functioned as the focus of archaeological investigation in Trinidad until 1967 (when Bullbrook died). In July 1969 Fred Olsen, José M. Cruxent and Irving B. Rouse briefly visited Trinidad in order to collect charcoal samples for radiocarbon dating at the Cedros and Palo Seco sites. Unfortunately, the archaeological specimens they recovered on this expedition were lost during shipment to the U.S.A. (Olsen 1974:245-256).

**The Recent Period**

In the late 1960s the focus of archaeological activity shifted from northwest Trinidad to the southern portion of the island where Peter O'Brien Harris conducted

excavations at the pre-ceramic Banwari Trace midden site. In November 1969, the remains of a human skeleton were discovered at Banwari Trace. Lying on its left-hand side, in a typical Amerindian "crouched" burial position along a northwest axis (Harris 1971, 1973), Banwari Man was found 20-cm below the surface. Only two items were associated with the burial, a round pebble by the skull and needlepoint by the hip[6]. Banwari Man was apparently interred in a shell midden and subsequently covered by shell refuse. Based on its with stratigraphic location in the site's archaeological deposits, the burial was probably interred shortly before the end of the site's occupation, approximately 3,400 BC or 5,400 years ago (Harris 1971, 1973). Assisted by members of the Historical Society of Trinidad and Tobago in the 1970s, Harris also conducted field work in south Trinidad at various pre-ceramic and ceramic sites such as Poonah Road, St. John, Atagual, San Fernando-Carib Street, Icacos, Guayaguayare and St. Catherine's. Harris' fieldwork enabled him to develop the first detailed chrono-cultural sequence for the Archaic age of Trinidad and refine Rouse's framework for the ceramic period in both Trinidad and Tobago (Boomert 2000).

Harris joined forces with Arie Boomert after the latter's appointment as Lecturer in Archaeology at the University of the West Indies (U.W.I.) in St. Augustine (Trinidad) in 1980. An Archaeological Research Centre at U.W.I was founded shortly thereafter, which at present functions as the focal point of archaeological research in Trinidad and Tobago. In 1982 Harris and Boomert jointly excavated a number of burials at Atagual in central Trinidad (Boomert 2000). The following year a similar joint fieldwork was conducted at a number of late-prehistoric and protohistoric middens in south Trinidad, for

[6] The presence of a needlepoint suggests that the human remains may be female.

example, Guayaguayare, Point Radix, and Batiment Crasé, resulting in the definition of the Guayabitoid and Mayoid series (Boomert 1985). Assisted by students of St. George's College, Bartaria, Boomert investigated the Blanchisseuse site on the north coast in November/December 1986. Numerous other Trinidad and Tobago sites were relocated and surveyed by Harris and Boomert as part of an ongoing project designed to provide a comprehensive inventory of all known prehistoric and protohistoric archaeological sites on the twin islands. This project resulted in a general listing and classification in terms of cultural resource management of all known sites (Boomert and Harris 1988) as well as detailed inventories of north, south and southeast Trinidad. In addition, between July 1992 and July 1993 Nicholas Saunders and Archibald S. Chauharjarsingh systematically mapped several pre-Columbian sites in southwest Trinidad (Boomert 2000).

In 1997 a program of cooperation between U.W.I. and Leiden State University of the Netherlands, resulted in the investigation of the Manzanilla 1 shell midden site of east Trinidad. The work was conducted over a three-month period by a group of Dutch students, led by Corinne L. Hoffman, Menno L.P. Hoogland and Boomert (Boomert 2000). During the project, augering revealed important features about the layout of the Manzanilla I site (Dorst 2001:2). Examination of a total of 98 shovel tests and borings covering the entire area of the site showed a configuration of relatively shallow and dense middens; the latter with a depth of up to 180 cm thick. Dorst (2001:2) contends that the former probably represent patches of open spaces (habitation areas) while the latter might formerly have been midden areas. The thickest midden deposits are located at the highest parts of the hill slopes, just over the edge of the plateau, closely encircling the habitation areas (Dorst 2001:2). The data also suggest that the habitation zones might have

coalesced round about a central plaza or "swept area" (Dorst 2001), a pattern that accords well with Saladoid village layout throughout the Caribbean (see Siegel 1996a). Follow-up work at the Manzanilla site in September 2001 unearthed 18 primary and secondary human burials, samples of which are being utilized for radiocarbon and isotopic analysis (Dorst 2002). Archaeological research at Manzanilla has also prompted the reconstruction of Trinidad's paleoenvironment on the basis of mollusks retrieved from the site (see Nieweg 2000).

## Current State of Knowledge on Trinidad's Pre-Columbian past

Archaeological research in Trinidad, though spasmodic, has yielded some insights into the island's prehistory. The major cultural periods, as described by Boomert (2000), are Archaic, Saladoid, Guayabitoid and Mayoid (see Figures 3-1 and 3-2 for cultural sequences and related time periods for Trinidad and Tobago). The following is a summary of the above-mentioned cultural sequences

### Archaic (Ortoiroid) Peoples (5000 BC - 200 BC)

Migrating from northeast South America, early Archaic populations settled in Trinidad around 5000 BC. They include eleven midden sites, five flint deposits and thirteen individual finds (Boomert 2000:54). Most of the approximately 29 Archaic sites identified in Trinidad (see Figure 3-3) are to be found in the southern half of the island. Culturally all Archaic sites in Trinidad can be assigned to a single tradition, the Ortoiroid series [7]. Two Ortoiroid subseries may be distinguished, Banwarian and Ortoiran, of which the former encompasses three individual cultural complexes, i.e. Banwari Trace

[7] This concept was introduced to Caribbean archaeology by Cruxent (1971:138) and Rouse & Allaire (1972:21, 1978).

and Poonah Road. Ortoiran includes one well-defined complex, Ortoire (Boomert 2000:55).

In addressing what constitutes the Archaic, R. Christopher Goodwin (1978) recognized two different perspectives: first, the Archaic as an age defined by the absence of pottery and the presence of ground stone and/or shell; second, the Archaic as a developmental stage characterized by the marine-oriented subsistence that followed a terrestrial hunting-based economy (see Keegan 1994 pp. 265-266). Several Archaic sites have been identified throughout the West Indies, for example in St. Kitts (Armstrong 1978; Goodwin 1978), Nevis (Wilson, 1991), Antigua (Davis 1982, 1993; Nodine 1990; Stokes 1991) the U.S. Virgin Islands (Lundberg 1989, 1991), Antigua (Nodine 1990) along the north and south coasts of Haiti (Rouse 1992) and in the river valleys and along the coast of Dominican Republic and Cuba (Keegan 1994; Rouse 1992). However, of all the Archaic-age sites in the West Indies, Banwari Trace is the oldest, with radiocarbon dates indicating a chronology of approximately 7000 B.P.

The Banwari Trace and St. John shell deposits are to be found on the southern edge of the Oropouche Lagoon in southwest Trinidad. Both sites occupy the tops of Miocene hillocks, originally covered with deciduous seasonal forest, which rise high above the swamp (Boomert 2000:55). The St. John shell deposit was investigated by Rouse, who dug a 8 x 2 m trench (Excavation A) along its periphery in 1953, followed by Harris, who in 1972 excavated a 7 x 1 m trench (Excavation B) from the estimated center to the perimeter of the midden (P.O. Harris 1976; Rouse 1953). In 1969/70 and 1971, Banwari Trace was excavated by Harris who dug a 2 x 2 m section (Excavation A) and an adjoining 2 x 1 m section (Excavation B) in the center of the midden.

The Archaic age material culture of Trinidad falls within the ambit of Goodwin's (1978) definition. The Banwari Trace complex, for example, bears a cultural assemblage, typically consisting of artifacts made of stone and bone (P.O. Harris 1971, 1972, 1973, 1976). Objects associated with hunting and fishing include bone projectile points, most likely used for tipping arrows and fish spears and beveled peccary teeth used as fishhooks. A variety of ground stone tools were manufactured for the processing of vegetables, including blunt or pointed, conical pestles, large grinding stones and round to oval *manos* (Boomert 2000:58).

**Saladoid Peoples (250 BC – AD 600)**

The first ceramic-age peoples who moved into the Caribbean in the last centuries B.C. have come to be called Saladoid, after the archaeological site *Saladero* in Venezuela at which their characteristic pottery was first identified and classified (Wilson 1997b). The origins of the Saladoids can be traced to the banks of the Orinoco, Venezuela (Rouse 1989). As early as 2100 B.C. villages of horticulturalists who used pottery vessels to cook their food had been established along the Middle Orinoco. During the ensuing two millennia their population increased and they expanded downriver and outward along the Orinoco's tributaries (Keegan 1992; Lathrap 1977, 1987; Roosevelt 1980).

Due to its geographical situation, Trinidad is often considered to have played a crucial role as one of the first stepping-stones in the movement of Saladoid peoples from the mainland of South America to the Antillean archipelago (Siegel 1989). As it is composed of beaches, sandy ridges, and low hills, interspersed among poorly drained areas like those in the Guianas, Rouse (1992:78) argues that the southern half of Trinidad must have seemed particularly attractive to the Saladoids from the mainland. (Figure 3-4

depicts a map of Trinidad showing the location of several known Saladoid sites). When Rouse developed the first framework of Trinidad's prehistoric chronology, he distinguished six "periods" of ceramic settlement in the island (Rouse 1947). The first four Ceramic Periods in this sequence are defined by two Saladoid "styles": the Cedros[8] and Palo Seco[9] complexes[10] named after midden[11] sites in southwest Trinidad. Radiocarbon dates provide a chronology of 2,140 B.P. for the Cedros complex. Radiocarbon dates from Cedros and Palo Seco complex sites suggest that the Saladoid occupation of Trinidad was well established by the third to second century cal BC (Boomert 2000).

Saladoid sites are to be found in practically all parts of Trinidad. Settlement sites and individual finds of the Palo Seco complex are especially well distributed in southwest Trinidad, Mayaro, the Central Range as well as the western portions of the Northern Range (Boomert 2000:145). Approximately 37 Saladoid sites have been identified in Trinidad (Boomert 2000). Of this number, Saladoid settlement sites (defined by the presence of midden deposits) predominate (64.9%) (Boomert 2000).

[8] Spanning the period 250 BC to AD 1, the Cedros "style" pottery is thin, hard and fine and contains grit temper (Boomert 2000; Rouse 1947). Vessel decoration is concentrated on the rim and the inner or outer surfaces of the vessel shoulders. The most diagnostic motif is comprised of finely incised, zoned crosshatches (ZIC), which in Rouse's opinion, in Trinidad is limited to the Cedros complex. Cedros complex is also characterized by white on red decoration (WOR) as well as simple lugs and anthropozoomorphic head lugs, typically showing concave backs.

[9] The Palo Seco complex sites date from AD 1 to AD 650 (Boomert 2000). The typical characteristics of Palo Seco pottery are moderately thick, coarse and soft, grit-tempered pottery, geometric lugs and modelled incised *adornos*, few of which show concave backs (Boomert 2000).

[10] The local chronological unit is the "complex," which is normally named after its type-site. It can be defined as the pattern of diagnostic cultural traits of a number of related archaeological assemblages, representing the material culture of a particular group of people.

[11] Middens are prehistoric refuse heaps.

Trinidad was also settled by Barrancoid peoples who exerted considerable influence Saladoid cultural traditions after AD 250. According to Rouse (1992) the Barrancoid peoples, who appear to have developed during the second millennium B.C., expanded downstream at the beginning of the first millennium B.C., pushing the contemporaneous Saladero people past the delta to the coast. The movement of the Saladoid peoples from the lower Orinoco Valley into the Guianas and Trinidad is an example of external pressure; these people were apparently pushed through the Orinoco Delta by the Barrancoid invaders from further upstream (Rouse 1992). Between AD 250 and AD 300, a local Barrancoid complex, Erin[12], was established in south Trinidad (Boomert 2000:239). While this Barrancoid movement from the South American mainland in to the West Indies was not pursued beyond south Trinidad, the inception of the Erin complex ushered in an epoch characterized by profound Barrancoid stylistic influence on the Saladoid. (Boomert 2000:239) contends that Barrancoid influence was particularly evident during the latter part of the Palo Seco complex of Trinidad. This, in his view, reflected intense interaction between the Erinan cultures of the mainland and south Trinidad on the one hand and the Late Cedrosan Saladoid communities of the entire coastal zone of northeast South America and the Antilles on the other hand [13].

Peter Roe (1989, 1991) posits that Saladoid potters (including those in Trinidad) showed a special fondness for the representation of personages, sacred animals, and fantastic creatures. The bodies and heads of zoomorphic, anthropomorphic, and

[12] Barrancoid pottery styles consist predominantly of open bowls showing heavy flanged rims and modeled-incised head lugs (Boomert 2000).

[13] Specific resemblances exist between particular Late Cedrosan Saladoid and Erinan adornos, especially long-snouted zoomorphic specimens, perhaps, representing bats and/or reptiles, and human-like faces showing exposed teeth (e.g. Chanlatte-Baik 1976:16).

anthropozoomorphic figures and fantastical creatures were used to adorn the effigy vessels. All of these clearly suggest a complex system of supernatural and mythological representations (Rodríguez 1997:84). It also suggests that Saladoids, through their ceramic art, maintained a strong mythological connection with the South American mainland (Roe 1995).

**The Guayabitoid Series (AD 650 –1300)**

Evidence for the existence of another mainland ceramic series in Trinidad, called Arauquinoid, is presented by Harris in his modification of Rouse's sequential cultural framework for the island (Harris 1978). The Arauquinoid series is called Guayabitoid in Trinidad and in the north-eastern part of Venezuela mainly because only some traits of this series diffused to Trinidad during this period (Dorst 2000:35). According to Harris (1978), the collapse of Barrancoid communities in the middle Orinoco on the South American mainland (around AD 650) facilitated Arauquinoid expansion from the Orinoco Delta to the Caribbean's most southerly island. The Guayabitoid series can be divided into four complexes: St. Catherine's, Bontour, St. Joseph and Marac.

The St. Catherine's complex, named after the site of St. Catherine, consists of a shell midden in southeast Trinidad, ca. 1.5-km inland from the south coast. This complex is characterized by pottery with medium-thick walls. Globular jars, generally with S-shaped profiles called *ollas*, simple unrestricted bowls with internally thickened rims, and *canaris*, relatively large jars with sharply everted, straight rims dominate the artifactual assemblage (Dorst 2000:36)[14]. Pottery is tempered with sand, shell and a new temper

[14] Decoration types vary from shallow, incised lines or punctuations or a combination of both. Motifs are simple – ovals and circles with or without central punctuation and lines ending in dots, short lines and dots on everted rims (Harris 1978). Modeled motifs include appliqué in "snake" pattern, small punctuated knobs

*cauixi*[15], a freshwater sponge, the use of which originated in the Amazon and the Guianas. Dorst (2000:36) is of the view that the St. Catherine's complex appears to be a blend of Barrancoid and the Arauquinoid of the South American mainland[16]. Given its prevalence at a number of sites on the mainland, this mixture suggests that there was considerable interaction between Barrancoid and Arauquinoid peoples on the mainland, which was later reflected in the Guayabitoid pottery of St. Catherine (Boomert 1985).

The Bontour complex has a time-span of between AD 650 and 1400 and is named after the type-site, Bontour, by Rouse (1947). Rouse (1947) defined this style on the basis of his excavations at this site in 1946. This complex is considered to have developed out of the St. Catherine's complex (Boomert 1993:101). Bontour ceramics are characterized by relatively soft, thin walls, predominantly tempered with shell and ground sherd and sand (Dorst 2000:36). Minor temper types are mica, *cauixi* and *caraipe*[17].

The St. Joseph complex site is situated in the center of the town of St. Joseph at the entrance of a valley in the Northern Range. Excavated by Goggin in 1953, the site dates from ca. AD 800 to 1400. The pottery shows close resemblances to the Bontour complex, except for the fact the majority of the St. Joseph ceramics are tempered with local

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or pellets and rim lobes, modeled-incised faces (Boomert 1985) and the characteristic petty modeling (Harris 1978).

[15] Several species: Drulia sp., Trochospongilla sp., Stratospongilla sp.

[16] Arauquinoid traits include *cauixi* temper, ollas vessel types and decoration modes such as short lines and dots on everted rims while Barrancoid culture traits include modeled-incised human and animal faces as well as incisions ending in dots (Dorst 2000:36).

[17] Boomert and Harris (1984) consider these three temper variations as reflecting social relationships between Bontour and other areas in Trinidad. Mica is found in the Paria Mountains of northern Trinidad and/or north-eastern Venezuela. Cauixi and caraipe are also considered to be non-local, the former is probably derived from the Lower Orinoco region and the latter is thought to be have accessed via trade from the Guianas (Boomert 2000).

Northern Range river sand (containing waterworn quartz and mica schist properties) (Dorst 2000:37). While most Guayabitoid complex sites are shell middens, located near the coast, the St. Joseph complex is located inland (Dorst 2000:37).

The Marac complex, dating from AD 1200 to 1400, is also considered to have developed out of the Bontour complex and represents the latest known complex of the Guayabitoid series. Its type-site Marac was probably discovered by Bullbrook and Parkinson in 1919. Marac pottery is predominantly tempered with ground potsherds, and a much lesser extent with sand and/or *caraipe*. At least two other Marac sites have been examined: Grant's Trace and Sylvester Trace, all of which including Marac itself are situated on forested, inland ridges (Dorst 2000:38).

Anna Roosevelt (1997:168-169) provides evidence, which suggests that the Arauquinoid peoples of the mainland and by extension, the Guayabitoid peoples of Trinidad had chiefdom societies. According to Roosevelt (1997) the anthropomorphic imagery of the Arauquinoid peoples was associated with some form of a chiefly cult, glorifying the memorial images of the ancestors of an elite people. The Arauquinoid period (AD 900 – 1300) was essentially characterized by incipient maize cultivation and the emergence of ranked societies in the Middle Orinoco (Roosevelt 1997:168-169).

**The Mayoid Cultural Tradition (AD 1300-1800)**

The Bontour complex (of the Guayabitoid series) of Trinidad might have been terminated by a small population influx from the South American mainland into Trinidad, giving rise to the development of a new ceramic tradition, the Mayoid series (Boomert 1985:23). The Mayoid series can be subdivided into a pre-Columbian complex, the Guayaguare complex and a historic complex called the Mayo complex.

The Guayaguayare complex represents the earliest representative of the Mayoid series in Trinidad, although the possibility exists that similar refuse may also be found at Icacos in the extreme western part of Trinidad's south coast (Boomert 1985:23). Surface collections were made by Josa in 1975 and Harris and Boomert in 1980. Radiocarbon dates yielded dates between AD 1320 and 1425 (Dorst 2000:39). Pottery of this complex is exclusively tempered with *caraipe*[18]. Dominant vessel shapes show simple forms, namely, unrestricted and restricted bowls. There is also a significant reduction of the olla type, which is now replaced by a necked jar with composite contours as well as straight or slightly curving thin walled everted necks (Dorst 2000:39). Only about one percent of the sherds are decorated with predominantly punctuated or nicked rim and wall knobs (Boomert 1985).

The Mayo complex is the second and final complex of the Mayoid series of Trinidad. It is known from at least three sites in the southwest of the island, Mayo, Princess Town and Savaneta-2, but similar deposits may occur at Union (Rouse 1953; see Boomert 1985:27). Other Mayo sites are Manzanilla II (SAN 3) located on the shores of North Manzanilla Bay and Sieudath Trace (NAR 6), situated on a 60-meter high ridge between the Rivulet River and the Sawonetta River. The first three sites represent the remains of former Spanish/ Amerindian missions dating back to the late seventeenth century and eighteenth centuries. The latter were founded by Capuchin missionaries as

[18] This is the ash of the siliceous bark of small tree, Licania apetala, which is locally known among the Amerindians of the Amazon Valley and the Guianas as "coupepia," "kwepi" (Kalina, Suriname) or "kauta" (Arawak, Guyana and Suriname). At present it forms the only tempering material the Indians in the coastal part of the Guianas use for their pottery (Boomert 2000). The bark is burnt, resulting in the removal of most organic components, and afterwards pounded. Temper consists of a mixture of white and gray siliceous particles, columnar and cellular in structure, and grains of carbonized organic material (Boomert 1985:24).

part of an attempt by the Spanish Government to assimilate Trinidadian Amerindians into Spanish culture and to convert them to Christianity (Boomert 1985:28).

The Mayo complex evolved out of the former Guayaguayare complex. Ceramics belonging to the Mayo complex have *caraipe* temper. In addition, the pottery shapes are exclusively simple bowls and buck-pots with thin necks, both types bearing flat bases and flattened and/ or beveled lips like those of the Guayaguayare complex. Decorations consist only of plain and nicked rim and wall knobs and occasional small rim lobes or simple red-painted designs (Dorst 2000:39). The Mayoid series represents a cultural tradition that might have been practiced extensively by a slew of Amerindian groups in Trinidad, such as the Carinepagoto, Yaio and Nepoio (Boomert 2000).

**Conclusion**

A number of conclusions may be drawn from the above discussion. Firstly, Boomert's three-step chronological classification of Trinidad's archaeological development is, to some extent, reflective of general trends in New World Archaeology from the late $19^{th}$ century to the present. The major periods in New World Archaeology are Classificatory-Descriptive (1840-1914), Classificatory-Historical: Concern with Chronology (1914-1940), Classificatory-Historical: Concern with Context and Function (1940-1960) and the Modern Period (of both Processual and Post-processual Archaeology) 1960-1992 (Willey and Sabloff 1993). It is important to note that these classifications rather than being discrete, bounded entities have, to a considerable extent, overlapping time frames.

The principal focus of the Classificatory-Descriptive period (1840-1914) was on the description of archaeological materials, especially architecture and monuments, and

rudimentary classification of these materials. Throughout this period there was a steady increase in the discovery and description of antiquities as the United States expanded westward and as Euro-Americans penetrated into other parts of the North and South American continents. In the United States, this work was sponsored by the government, universities, museums, and scientific societies Willey and Sabloff (1993:38-39). This period was also generally characterized by a lack of rigorous chronological perspective and the development of methods that would lead to such a perspective. The detailed publications of Sir William Robinson's prehistoric findings at Erin by J.H. Collens and the work of J.W. Fewkes and Theodore Booy in Trinidad, carried out under the umbrella of established American museums, were indeed characteristic of this period. Bullbrook's 1919 excavations at Palo Seco accorded well with the Classificatory-Historical Period: the Concern with Chronology (1914-1940), which saw stratigraphic excavation as the primary method in the drive for chronological control of archaeological data (Willey and Sabloff 1993). Although earlier attempts had been made to ascribe use or function to archaeological artifacts, the Classificatory-Historical Period: the Concern with Context and Function (1940-1960) was different in the sense that it paid close attention to context in arriving at functional inferences (Willey and Sabloff 1993). Surveys and excavations by Irving Rouse in southwest Trinidad in 1946, which later formed the basis of a pre-Columbian time-space systematics for the island (Boomert 2000) clearly fell within the ambit of this period. Cultural materialism of the Modern Period (which posits that environmental, technological and economic factors—the material conditions of existence—are the most powerful and pervasive determinants of human behavior) (see

Harris 1979), are defining characteristics of recent research projects in Trinidad spearheaded by Boomert (2000), Dorst (2001, 2002) and Nieweg (2000).

Secondly, despite the efforts of a motley collection of amateur and professional archaeologists from the 19th to the present, pre-Columbian archaeological research in Trinidad continues to essentially be a collage of site inventories and stratigraphic profiles (from the Archaic to the Mayoid periods), slavishly couched within Rouse's time-space systematics. With the survey and excavation at Manzanilla being the singular exception (Dorst 2001, 2002), there is little or no information about inter-site and intra-site spatial relationships as well as the relationships between sites and the biophysical properties of the landscape on a regional scale. Spatial studies in archaeology that have been carried out in the Americas including the Caribbean since the advent of Gordon Willey's 1946 Virú Valley in Peru (see Billman 1999 and Feinmann; Curet 1992; Willey and Sabloff 1993:172; Zeidler 1995) have clearly not been extended to Trinidad. The proposed GIS study is therefore necessary, as it will provide predictive models for more effectively managing the myriad archaeological sites of Trinidad.

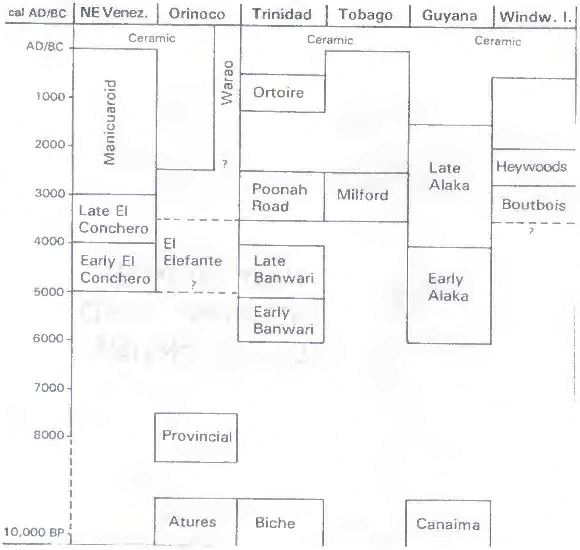


Figure 3-1. Chronological chart of the Archaic Ages in Trinidad and the South Caribbean according to calibrated radiocarbon dates. (Source: *Trinidad, Tobago and the Lower Orinoco Interaction Sphere* by Arie Boomert, Cairi Publications, Alkmaar 2000, pp. 54-55).

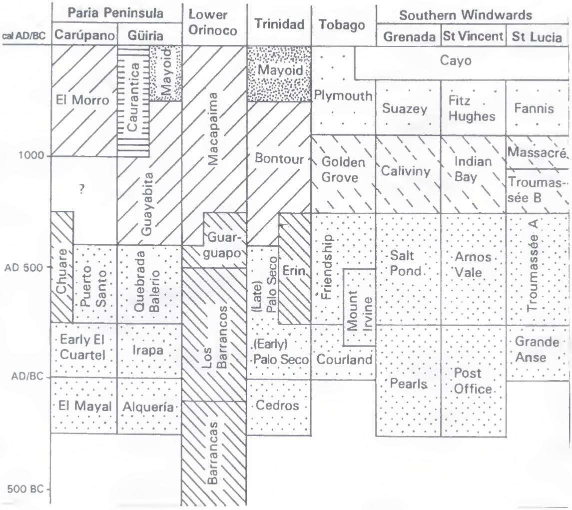


Figure 3-2. Chronological chart of the ceramic age in Trinidad and the Southern Caribbean. (Source: *Trinidad, Tobago and the Lower Orinoco Interaction Sphere* by Arie Boomert, Cairi Publications, Alkmaar 2000, p. 128).

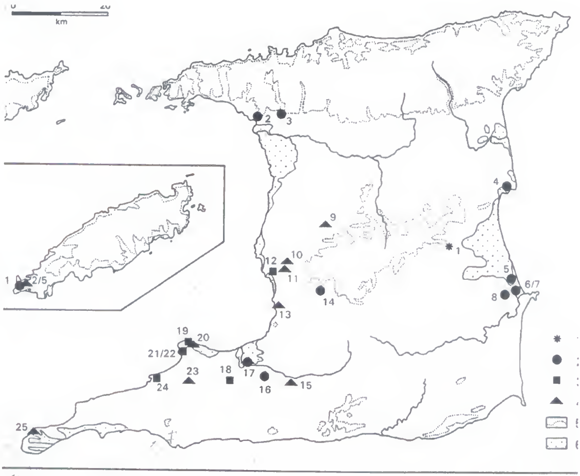


Fig. 5. Map of Trinidad and Tobago (inset), showing the locations of Lithic and Archaic sites. *Legend:* (1) individual find (Lithic); (2) midden sites (Archaic); (3) flint deposits (Archaic); (4) individual finds (Archaic); (5) 100 meter contour line, (6) swamps and marshes. *Key to Trinidad sites:* (1) Biche; (2) Laventille; (3) San Juan; (4) North Manzanilla 2; (5) Kernahan Trace; (6) Cocal 1; (7) Ortoire; (8) Chip Chip Hill; (9) Arena Reservoir; (10) Basterhall Reservoir; (11) Belle Vue, (12) Savaneta 1, (13) Pointe-à-Pierre 1; (14) Poonah Road; (15) Lawrence Hill; (16) Banwari Trace; (17) St John; (18) Fyzabad; (19) Pointe d'Or 1; (20) Pointe d'Or 2; (21) Pitch Lake 1; (22) Pitch Lake 3; (23) Parrylands; (24) Point Fortin 1; (25) Columbus Estate. *Key to Tobago sites:* (1) Milford 1; (2) Bon Accord 1; (3) Bon Accord 2; (4) Bon Accord 3; (5) Bon Accord 4.

Figure 3-3. Map of Trinidad and Tobago (inset) showing the locations of Archaic sites. (Source: *Trinidad, Tobago and the Lower Orinoco Interaction Sphere* by Arie Boomert, Cairi Publications, Alkmaar 2000, pp. 48-49).

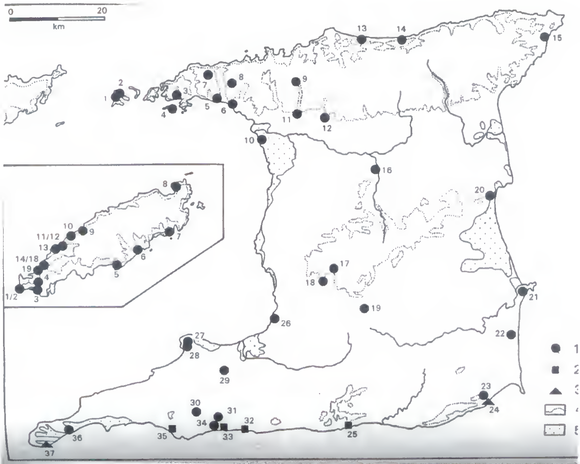


Fig 16 Map of Trinidad and Tobago (inset), showing Early Ceramic sites. *Legend:* (1) Cedrosan Saladoid (middens, midden/burials and individual finds); (2) Cedrosan Saladoid & Erinan Barrancoid (middens, midden/burials and individual finds); (3) Barrancoid (individual finds and 'trade' materials in Late-Ceramic complexes); (4) 100 meter contour line, (5) swamps and marshes. *Key to Trinidad sites:* (1) Perruquier Bay, Chacachacare Island; (2) Sanders Bay, Chacachacare Island, (3) Chaguaramas; (4) Bombshell Bay, Caspar Grande Island; (5) Bayshore; (6) Mucurapo 1; (7) Morne Jean; (8) Morne Coco; (9) Maracas; (10) Blue River; (11) St Joseph 3; (12) Tacarigua; (13) Blanchisseuse; (14) Tacarib; (15) Redhead, Cumana Bay; (16) Arena Road; (17) Atagual; (18) Whitelands; (19) Mendoza-La Gloria; (20) Manzanilla 1; (21) St Bernard; (22) Lagon Doux 1; (23) St Catherine's; (24) Guayaguayare; (25) La Lune 1; (26) San Fernando–Carib Street; (27) Pitch Lake 1; (28) Pitch Lake 2; (29) Delhi Road; (30) Carapal; (31) Grand Ravine; (32) Quinam; (33) Chagonaray; (34) Palo Seco; (35) Erin; (36) Cedros; (37) Icacos. *Key to Tobago sites:* (1) Sandy Point; (2) Crown Point; (3) Friendship; (4) Golden Grove; (5) Granby Point; (6) Goldsborough 1; (7) Queen's Bay; (8) Pirates' Bay; (9) King Peter's Bay; (10) Culloden Bay; (11) Arnos Vale Sugar Estate; (12) Arnos Vale Bay, (13) Lovers' Retreat, (14) Rocky Point; (15) Mount Irvine 1; (16) Mount Irvine 2; (17) Mount Irvine 3, (18) Mount Irvine 4; (19) Buccoo 2.

Figure 3-4. Map of Trinidad and Tobago showing the locations of early ceramic sites. (Source: *Trinidad, Tobago and the Lower Orinoco Interaction Sphere* by Arie Boomert, Cairi Publications, Alkmaar 2000, pp. 130-131).

# CHAPTER 4

# SETTLEMENT ARCHAEOLOGY AND GEOGRAPHIC INFORMATION SYSTEMS

## Settlement Archaeology: Definitions and Conceptual Framework

Settlement archaeology may be succinctly defined as the study of the internal structure, arrangement, distribution, and relationships of ancient settlements in the context of their environmental setting and landscape position (Darvill 2002:385). Central to settlement archaeology is the concept of settlement pattern. In Willey's (1953:1) view, settlement patterns reflect "the way in which man disposed himself over the landscape on which he lived. It refers to dwellings, to their arrangement, and to the nature and disposition of other buildings pertaining to community life." These settlements reflect the natural environment, the level of technology on which the builders operated, and various institutions of social interaction and control, which the culture maintained (Willey 1953:1). Because settlement patterns are, to a large extent, directly shaped by widely held cultural needs, they offer a strategic starting point for the functional interpretation of archaeological cultures (Willey 1953:1). Pointing to its validity as one of the most encompassing constructs of the discipline of archaeology, Fish (1999:203) argues that a settlement pattern in its archaeologically tangible expression is a set of culturally significant locations, each of which occupies a specified position within an array that makes up a coherent distribution (Fish 1999:203). We visualize these distributions in the context of maps that summarize the natural features on which they occur. Thus settlement patterns are spatial matrices marking the intersection of human

activities and the natural environment. As such, they provide a basis for examining the relationship between cultural loci and relevant geographic variables (Fish 1999:203).

**Settlement Archaeology and Cultural Materialism**

The concept of settlement archaeology, as defined by Darvill (2002), Fish (1999) and Willey (1953) clearly fits within the mould of cultural materialism. According to Thomas (1999:48-52), processual archaeology invariably applies the strategy of cultural materialism to evidence from the past. First introduced by Marvin Harris (1968), cultural materialism is a scientific research strategy that prioritizes material, behavior and etic processes in the explanation of the evolution of human socio-cultural systems. Cultural materialists use the term infrastructure to denote those elements considered most important to satisfying basic human needs: the demographic, technological, economic, and ecological processes - the modes of production and reproduction – that are assumed to lie at the causal heart of every socio-cultural system. Specifically, it is the behavioral infrastructure that mediates a culture's interactions with the natural and social environment (Thomas 1999:48; Harris 1968, 1979). At the next level, the sociocultural subsystem is made up of those interpersonal relationships that emerge as behavior: social organization, kinship, economics, ethics, and military, and political organization. This sociocultural subsystem is today subsumed by the term structure. Finally, the term superstructure refers to values, aesthetics, rules, beliefs, religions, and symbols. Expressed in etic behavioral terms, superstructure is manifested as art, music, dance, literature, advertising, religious rituals, sports, games, hobbies, and even science (Thomas 1999:49; Harris 1968).

What distinguishes cultural materialism from other approaches is the principle of infrastructural determinism or environmental determinism, which has two basic premises: (1) that human society strives to optimize the costs and benefits for those genetically derived needs most important to the survival and well-being of human individuals (sex, sleep, nutrition, vulnerability to stress, and so forth), which occur primarily in the etic behavioral infrastructure; and (2) that such infrastructural changes determine changes in the rest of the sociocultural system (Thomas 1999:49-52).

Clearly therefore, the concept of settlement archaeology is decidedly processual, as it is based on the assumption that environments were a significant determinant in settlement choice (Warren 1990:202). Access to water, geomorphology, vegetation, soil types, slope, aspect, elevation are just a few of the environmental variables generally considered important for locational decisions (Warren 1990; Wescott and Brandon 2000).

**Post-Processual Approaches to Settlement Archaeology**

However, since the 1970s and 1980s, processual approaches to settlement studies have come under increasing attack from adherents of post-processual archaeology. The post-processual critique rejects the etic, evolutionary, antihistorical, objective, science-based, and ethical neutrality of the processual agenda. Consistent with postmodern interpretivism, the postprocessual critique holds that universal laws of human behavior simply do not exist (Thomas 1999:54). Postprocessual critiques have significantly generated academic debates outside the Americas (with growing impact in the latter as well), focusing attention on the active role of individuals in constructing and interpreting the world around them, and in continually reshaping culture and society (Knapp and Ashmore 1999:7), a process described by Brumfiel (1992:559) as contingent, negotiated

and based on the "compromise outcome of strategy, counterstrategy, and the unforeseen consequences of human action." Symbolic expression is central to maintaining communication and social integration, but these shared symbols become reworked in individual use (Knapp and Ashmore 1999:7). Structuration (Giddens 1984), practice (e.g. Bourdieu 1977) and feminist theory (e.g. Conkey and Gero 1997; Wylie 1992) as well as phenomenology (e.g. Gosden 1994; Thomas 1996) have proven useful to many analysts in deciphering the form and meaning of symbolic expressions in the past.

In regards to postprocessual approaches, local physiographic features are recognized increasingly as the source and subjects of the symbols, often linked to ancestral beings (Morphy 1995:186-8). According to Knapp and Ashmore (1999:8), in the archaeologies of landscape, the effect has often been to regard such features and their meanings as mediating the selection, use, modification or avoidance of particular locales. Landscape as actively inhabited space, and particularly landscape as the arena for ritual or ceremonial activity have, in recent years, become important themes in archaeology (e.g. Alcock 1993; Bradley 1993; Derks 1997; Schmidt 1996, 1997).

In light of this postprocessual trend, the settlement pattern concept is not without its critics. Advocates of "siteless" archaeology challenge the notion of sites, the bounded spatial entities of which settlement patterns are composed. Knapp and Ashmore (1999:2) assert that, recent times, archaeologists have expanded their gaze beyond the isolable "hot spots" termed sites, to consider a more comprehensive distribution of human traces in and between loci, now often termed "places of special interest" (see Cherry et al. 1991). The resulting perspectives are invariably termed siteless archaeology (e.g. Dunnell 1992), off-site archaeology (e.g. Foley 1981), distributional archaeology (e.g. Ebert 1992), and

several approaches that fall under the rubric of landscape archaeology. In practice, these diverse approaches facilitate the study of diffuse human remains – such as field systems, industrial sites, roads, and the generally ephemeral traces of non-sedentary peoples that never fit comfortably within traditional operational definitions of "sites."

A similar view is echoed by Marquardt and Crumley (1987) in their treatise on spatial patterning. Indeed, Marquardt and Crumley (1987) assert that societies are formed by their natural and constructed environments and the landscape is essentially the spatial manifestation of the relations between humans and the environment. Included in the study of landscapes are population agglomerations of all sizes, from isolated farmsteads to metropleis, as well as the roads that link them (Marquardt and Crumley 1987). Also included are unoccupied or infrequently occupied places, such as religious shrines, resource extraction sites, river fords, passes through mountains, and other topographical features that societies use and imbue with meaning (Marquardt and Crumley 1987). Ascribing significance to a special configuration of natural and geographic features is never self-evident but rather culturally determined (e.g. Hirsch 1995; Saunders 1994). Knapp and Ashmore (1999:2) describes the landscape perspective as more holistic as it compels us to underscore the interrelationships between people and such traces, places and features, in space and through time. In this regard, landscapes are seen as an active and far more complex entity in relation to human lives rather than merely "a passive backdrop or forcible determinant of culture" as suggested by the concept of settlement archaeology (Knapp and Ashmore 1999:2).

However, it would appear that in some respects the contrast between settlement patterns and "siteless" approaches may be overdrawn. It is true that settlement pattern

studies have tended to concentrate on research questions and societies for which architectural and residential locations are the most obstrusive and commonly interpreted entities. It is equally true that "siteless" archaeology has tended to focus on questions, societies, and activity sets characterized by an absence of sustained residence and by limited categories of dispersed remains (Fish 1999:204; see Knapp and Ashmore 1999; Dunnell 1992). However, with both approaches interpretation often hinges on the distributions and attributes of no more than a few classes of material culture and the activities they represent. Fish (1999) argues that the scholarly propensity to understand by disaggregating, dividing, and analyzing is counterbalanced by the need to reassemble and relate, to summarize and categorize. "Siteless" approaches are most suited to the former agenda, while the settlement pattern concept best serves the latter (Fish 1999:205). Therefore, it is arguably far more constructive incorporating dispersed and ephemeral remains into a settlement pattern model than to advocate abandoning it altogether. The settlement pattern concept is potentially as versatile as our ability to recognize and articulate a sense of distinctive place; it should accommodate loci of activities that are simple and fleeting as well as diverse and long-term (Fish 1999:205).

Fish (1999) argues that geographical information systems, given its penchant for handling spatial data sets, is increasingly been used in studies relating to settlement archaeology.

## Geographic Information Systems (GIS) Defined

Attempting to isolate one definition of GIS that functions universally has proven difficult, if not futile (Maguire 1991; Clarke1997; see Gourad 1999). The following definitions will demonstrate the nuances of the technology:

> A powerful set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. (Burrough 1986:6)

> A geographic information system is a special case of information systems where the database consists of observations on spatially distributed features, activities or events, which are definable in space as points, lines or areas. A geographic information system manipulates data about these points, line and areas to retrieve data for ad hoc queries and analyses. (Duecker 1979:106)

Although, there seems to be some disagreement on what GIS should accomplish, the common denominator of all definitions of all GIS is the manipulation of spatial data (Gourad 1999). Some CAD (Computer Aided Design) software systems are capable of manipulating data, but are not considered to be true GIS because of their limited analytical capabilities. It is generally believed that a true GIS ought to be able to combine different layers of digital spatial data and produce new outcomes (Gourad 1999).

However, Bernhardsen (1999:4) argues that the term geographical information system (GIS) is now used generically for any computer-based capability for the manipulation of geographical data. A GIS includes not only hardware and software, but also the special devices used to input maps and to create map products, together with the communication systems needed to link various elements. The hardware and software functions of a GIS specifically include:

- Acquisition and verification
- Compilation
- Storage
- Updating and changing
- Management and exchange
- Manipulation
- Retrieval and presentation
- Analysis and combination

All these actions and operations are applied by a GIS to the geographical data that form its database (Bernhardsen 1999:5).

Geographic location is the element that distinguishes geographic information from all other types. Methods for specifying location on the Earth's surface are essential to the creation of useful geographic information (Longley et al. 2001). All of the data in a GIS are georeferenced, that is, linked to a specific location on the surface of the Earth through a system of coordinates such as Latitude and Longitude and Universal Transverse Mercator (UTM). Geographical information attaches a variety of qualities and characteristics to geographical locations (Figure 4-1). These qualities may be physical parameters such a ground elevation, soil moisture level, or atmospheric temperature, as well as classifications according to the type of vegetation, ownership of land, zoning and so on. According to Bernardsen (1999:5) we use the general term attributes to refer to the qualities or characteristics of places, and think of them as one of the basic elements of geographical information, along with locations.

Geographic Information Systems combine the power of databases with graphic display. The database component of GIS consists of tabular records that are connected to each other via various means depending on the database, the most popular of which is currently the relational database (Gourad 1999). Tabular data are portrayed graphically within two formats, vector and raster (Mitchell 1999). Vector data structures are displayed through points, lines and polygons. Each feature is a row in a table, and the feature shapes are defined by x, y locations in space (the GIS connects the dots to draw line and outlines). Locations such as the address of a customer, the spot where a crime was committed, are represented as points having a pair of geographic coordinates

(Mitchell 1999:14). Lines, such as streams, roads, or pipelines, are represented as a series of coordinate pairs. Areas are defined by borders, and are represented by closed polygons. They can be legally defined, such as a parcel of land; administrative, such as counties; or naturally occurring boundaries, such as watersheds (Mitchell 1999:14). In contrast, a raster or grid format displays an image or map through pixels that carry inherent values (Gourad 1999). Each layer represents one attribute (although others can be attached), and most analysis occurs by combining the layers to create new layers with new cell values. The cell size used for a raster layer will affect the results of the analysis as well as graphic representation (Mitchell 1999:14). The cell size should be based on the original map scale and the minimum mapping unit. In Mitchell's opinion (1999:14) using too large a cell size will cause some information to be lost. Using a an overly small cell size requires a considerable amount of storage space and takes longer to process, while not necessarily enhancing map precision.

Another popular source of data is the Digital Elevation Model (DEM), from which a number of variables or derived from including slope, aspect, terrain roughness, and relief (Duncan and Beckman 2000:40). DEMs are ultimately a result of interpolation algorithms on a number of points that have x, y, and elevation values (see Bernhardsen 1999:85; Gourad 1999). The points are either sampled or systematically spaced (Theobald1989). It is important to know that when point data are converted to continuous data, error is likely to occur, regardless of how good the interpolation algorithms are. For example, DEMs derived from digitized 1:250,000 scale USGS maps have a horizontal error of ± 127 m; therefore, the unwary use of DEM data can produce significantly erroneous results (Walsh, 1990). In a landmark paper, Kvamme warned about the naïve

use of DEMs (Kvamme, 1990). The author compared two data sets. The US Army's defense Mapping Agency's DEM based on elevation contours of 1:250,000 scale maps and the USGS 7.5 minute series with a scale of 1:24,000. The results showed that a substantial amount of detail was lost in the low resolution DEMs (1:250,000 scale) sometimes with major landforms, minor drainage, ridges, and hills being either smoothed or totally absent from the data (Gourad 1999).

**The Role of GIS in Settlement Archaeology and Cultural Resource Management**

Archaeological data are spatial and temporal in nature, and therefore especially suited to the basic principles driving the development and use of GIS (Wescott 2000:1). Since the Virú Valley field project in Peru in 1946, which marked the beginning of settlement pattern research in the Americas, settlement archaeology has traditionally been based on hand-drawn maps and paper databases which at times were difficult to integrate and manipulate (Willey and Sabloff 1993:172; Wescott 2000:1). With the passage of over fifty years of settlement pattern research in the Americas, settlement pattern archaeology has come of age (Billman and Feinmann 1999:2). An important hallmark of the development of settlement archaeology is the successful integration of GIS in data collection and analysis, a process which begun in the 1980s.

Archaeological materials include both objects produced by human activity in the past, and sites of human activity. Humanly-modified landscapes, even those given mythological significance like a natural rock or a cave, can be considered cultural resources. The need to mnanage these resources comes from the realization that they are finite and diminishing (Drewett 2001:7). Although GIS is often used by planners to view the most current information about a geographical area, as Limp and Carr (1985) point

out, Gis has many applications in archaeological discovery, analysis, planning, and protection.

**Predictive Modeling and Cultural Resource Management**

The growing use and increasing sophistication of GIS methods in archaeology have produced a variety of studies, which have demonstrated its tremendous potential for interpretation and interrogation of spatially referenced data (Allen et al. 1990). The prediction of archaeological sites is one of the most obvious uses of this technology in relation to regional settlement studies (e.g. Brandt et al. 1992; Carmichael 1990). Defined as tools for projecting known patterns or relationships into unknown times or places (Warren and Asch 2000:6), predictive models are potentially useful in archaeology. The development and application of predictive models, which assess the probability of prehistoric archeological sites occurring across the landscape has greatly increased in recent years (Allen et al. 1990; Brandt et al. 1992; Carr 1985; Judge and Sebastian 1988; Phillips and Duncan 1992). The driving force behind this growth in predictive model development has been the need for the identification, protection, and management of increasingly threatened resources in a cost-effective and useful manner (Duncan and Beckman 2000:33). Warren and Asch (2000:6) contend that archaeologists have documented only a fraction of the millions of sites in the New World, while thousands of sites are destroyed each year to make way for ongoing land development. One way to help us understand and protect these sites is to create formal models capable of predicting where they are located (Warren and Asch 2000:6).

In cultural resource management, predictive models are typically probability surfaces of some kind: more simply they are maps that show how the probability of

encountering archaeological materials is expected to vary over the landscape. An underlying key to the success of predictive models is the fact that archaeological sites tend to recur in environmental settings favorable to human settlement (Warren 1990). Predictive models take advantage of such redundancies; they exploit contrasts between the environmental characteristics of places where sites do and do not occur. With appropriate data it is possible to make predictions from a relatively small sample of known locations to a much broader area (Warren and Asch 2000:6). Duncan and Beckman (2000:33) assert that the basis of such models is that the spatial distribution of cultural remains, which are often represented as archaeological sites, is the result of human decision-making activities within the possibilities and conditions presented by the environment. The development of most contemporary predictive models involves the consideration of multiple thematic layers of information relating to past environmental and/or cultural conditions. Interpreting the interplay between these multiple thematic layers and their various permutations may reveal identifiable patterns that reflect actual human patterns and choices (Kincaid 1988).

Most archaeological predictive models rest on two fundamental assumptions: first, that the settlement choices made by ancient peoples were strongly influenced or conditioned by characteristics of the natural environment; and second, that the environmental factors that directly influenced these choices are portrayed, at least indirectly, in modern maps of environmental variation across an areas of interest. Given these assumptions, it is possible to develop an empirical predictive model for any particular areas, as long as the area has been adequately sampled by archaeological surveys (Warren 1990:202). Several criteria can be used to judge the adequacy of

surveys, the most important of which is that they consistently distinguish between locations where sites are present and locations where sites are absent (sites versus nonsites, respectively). The distinction between sites and nonsites is important, as it provides a framework within which probabilities can be calculated (Kvamme 1983). Warren and Asch (2000:6-7) posit that this may be done by computing a statistical classification model that capitalizes on the measurable environmental differences between the two groups. Such models make it possible to estimate the probability that a site occurs at a given location simply by measuring an appropriate set of environmental variables (Warren and Asch 2000:7).

Archaeologists are becoming aware of the appropriate conceptual framework of predictive modeling, and the methods being used in predictive research are improving. Carr (1985) and Kohler and Parker (1986) present critical appraisals of archaeological predictive models. Both articles highlight key elements of the transition away from the traditional methods of settlement pattern research. Perhaps the most important change is the abandonment of the "site" and the adoption of the "land parcel" as the basic unit of analysis (Allen et al. 1990). This approach stems from the fact that the probability models require information on both positive and negative responses. In terminology used here, a positive response is a parcel that contains a site and a negative response is a parcel that lacks a site (nonsite) (Allen et al. 1990). The land parcel approach also is important because it is the only way to measure the relative effects that different independent variables have on site location (Kvamme 1983, 1985). In essence, land parcels provide background information of control data on environmental distributions in an area, against which the distributions of site locations can be compared (see Kellogg 1987).

Another important change is the move toward appropriate statistical procedures that are capable of converting information on site and nonsite locations into formal predictions of site-presence and site-absence probability (Allen et al. 1990). Two procedures—discriminant function analysis and logistic regression—produce formulae that yield probability estimates. However, comparisons of these procedures usually show that logistic regression outperforms discriminant function, particularly when independent variables do not have normal distributions (Allen et al. 1990). Logistic regression accepts mixtures of nominal, ordinal, interval, and ratio-scale independent variables, and it operates on either tabulated data or data with one subject case. Therefore, its output is a formula that provides readily interpretable predictions of site-presence and site-absence (Allen et al. 1990). It is important to recognize that while representing "sites" and "nonsites" as land parcels may be more suitable for logistic regression analysis, the representation of sites as training points is more appropriate in the application of the weights of evidence method, which determines the predictive strength of environmental features such as soil texture, land capability, and relief on the basis of the areal association between the training points and environmental data (Bonham-Carter 1994)

**Inductive versus Deductive Predictive Models**

It is important to note that predictive models, expressed in terms of probabilities, are essentially inductive or empirical predictive models of pattern recognition (Warren 1990). In essence, most of such models use statistical methods to extract from a sample of observations a formal decision rule, a rule that can be used to predict the composition of characteristics of future samples. One of the most powerful and widely used of the empirical methods is a set of procedures called probability models (Aldrich and Nelson

1984). These models are well suited for predicting the locations of archaeological sites, as they are designed to predict the responses of either/or situations (site presence versus site absence) to the interactions of independent variables (environmental measurements). The predictions themselves are expressed in terms of probabilities. Probabilities are readily interpretable and easily testable values that range between 0 (low probability) and 1 (high probability) (see Warren 1990).

Conceptually, it is possible to develop a predictive model either by pure deduction from theory or by pure induction from empirical observations. In practice, however, most models make use of both theory and observation. For example, models of archaeological site location could be developed using a deductive approach that stresses the theorized cultural and biological needs of society (Warren 1990:91). In this connection, the most coherent adaptive approach in anthropology is cultural materialism, which posits that environmental, technological and economic factors—the material conditions of existence—are the most powerful and pervasive determinants of human behavior (Harris 1979). Cultural materialism proposes that human populations adapt to their environments through culture-based behavioral systems (see Brumfiel 1992) seems to constitute the major paradigm for the conceptualization and mechanics of deductive GIS predictive models in archaeology.

Lock's "land evaluation" is a clear example of deductive predictive model rooted in cultural materialism (Kamermans 2000:124). Originally from soil science, "land evaluation" generates different models for land use on the basis of ecological and socio-economic data. Confronted with archaeological data, it predicts activity areas (Kamermans 2000:124). Under the rubric of cultural materialism, the application of "land

evaluation" in archaeology requires the following (arguable) assumptions: (1) Past human exploitation of the environment was based on the principle of least effort (2) The combination of the environment and human behavior creates a specific spatial pattern in particular types of areas (3) There is a relationship between prehistoric land use and artifact and site density and (4) The economic system during each archaeologically distinct period was, broadly speaking, constant (Kamermans 2000).

While purely deductive models can be developed in the absence of information on archaeological site location, they cannot be implemented or tested without such observations. Similarly, one could develop a purely inductive model of site location, but in the absence of theory the process of variable selection would be inefficient and the resulting model would run the risk of being weak and uninterpretable (Warren 1990:91). It is for this reason that predictive models are best constructed on the basis of a combination of inductive and theoretical constructs (see Warren 1990:91).

There are several examples of successful GIS-aided predictive models, which have provided accurate probability estimates of prehistoric site location in sample-surveyed areas. Only a select few will be mentioned here. The first example relates to a geographic information system (GIS) that was used by Skelly and Loy, Inc. of Monroeville, Pennsylvania to formulate models for site potential or archaeological resource sensitivity within four areas of Pennsylvania and West Virginia (Duncan and Beckman 2000:33). The resultant model produced for the Kanawha Rivers study area had site-potential scores ranging from 0 to 800 for 1.4 million cells, with the highest site potentials occurring within the well-drained soils of the Kanawha River floodplain (Duncan and Beckman 2000:54). However, areas of high potential for archaeological sites also occurred within

the uplands, particularly in the upland "hollows" and "passes" (Duncan and Beckman 2000:54). The second case study pertains to a GIS-aided archaeological survey conducted in the Montgomery county (Illinois), which revealed that prehistoric sites are most probable in areas with relatively rugged relief, where surface slopes are steep and runoff is rapid (Warren and Asch 2000:26). The third and final example focuses on the use of a GIS to model prehistoric site distributions in a largely unsurveyed coastal area of 39,000 acres (15,800 ha) in the Upper Chesapeake Bay (Maryland). The potential occurrence of sites in this area was assessed on the basis of environmental variables recorded from over 500 known sites in the region (Wescott and Kuiper 2000:59).

**Critique of GIS Predictive Models**

However, the use of GIS predictive models in settlement archaeology has not been without vociferous criticisms from those who consider this approach to be both intellectually narrow and environmental deterministic. Gaffney (1995:371) argues that not only is GIS, as used by many of its adherents, environmentally and functionally deterministic, and that such stances will ultimately be unproductive, but also that this situation results largely from unrestricted theoretical perspectives of all too many archaeologists currently using GIS as an analytical tool. These limitations are compounded by the repeated use of data types which most easily fit the prevalent GIS data model and that too little consideration is paid to whether these data sets allow valid descriptions of past societies or even settlement systems (Gaffney 1995:371).

In his discussion of inductive predictive modeling, Kamermans (2000:124) is of the view that although this approach is widely used in cultural resource management to predict archaeological site location, the fundamental flaw with this approach is that it

erroneously equates correlation with causality. With inductive predictive modeling in general no effort is made to try and understand the cultural and environmental mechanisms that are causing the correlations or to take distorting factors into account sufficiently (see Kamermans 2000). Distorting factors are often physical (for instance geological), which explain why some land units produce a less than expected frequency for archaeological find spots. In other words, a geological map will by definition produce different results to a soil map or geomorphological map (Kamermans 2000).

The worldview suggested by these models is one in which human action is essentially a passive adaptation or by-product of the economic system (see Hodder 1991:32-4). This attitude is closely linked with systems theory and, as Wheatly (1993) has already commented, such theoretical perspectives tend to be almost inevitably deterministic and characterized by analyses, which emphasize cross-cultural rules and metrical testing (Gaffney 1995). Social action is clearly seen as secondary and dependent upon the environment and the economy. In such a situation there is no other context for explanation other than within the environmental system, and abstract models provided through an environmentally deterministic viewpoint appear perfectly adequate descriptions of cultural remains (Gaffney 1995). In too many analyses, spatial relationships from such studies are subjected to a battery of descriptive statistics and the results held to have been vindicated (Wansleebem and Verhart 1995). In essence, this suggests a major confusion between the abstraction of patterns and their distributions (Gaffney 1995).

An issue that seems to cut at the heart of the GIS predictive models in archaeology is the unwitting emphasis on settlement location (Judge and Sebastian 1988; Kvamme

and Kohler 1988). Even where this is not explicit it may be observed that there is also a tendency for several GIS models to explain the location of "sites" without any qualitative descriptive of what a site means. Gaffney (1995) argues that, at the risk of generalization, it appears that in most applications, it is frequently assumed that these sites are in fact "settlements," i.e. habitation sites where most day-to-day economic activities are carried out. The vexed question of how we should map and display archaeological data has been with us for decades. Archaeological and ethnographic literature relating to the nature of human systems and the structuring of their residues suggest that the concept of the archaeological site is an adequate description of human remains and that settlement sites rarely reflect the full range of human activities, many of which are differentially distributed throughout space (Foley 1981). "Sites," as such, only come to prominence because of the intensity of activities which occur at these loci and the concomitant chance of increased material residue discard and subsequent discovery (Gaffney and Tingle 1984). This complexity is rarely reflected within GIS models, which all too frequently present human activity as a series of isolated points (sites/settlements) without reference to the continuous activity that occurred across the landscape (e.g. van Leusen 1993).

There is another related point. Having simplified a vastly complex landscape record into a few spatially discrete, unrepresentative points, many GIS practitioners then ignore the qualitative data that are derived from the excavation and surveys of many of these sites/ settlements. Despite the voluminous evidence, which suggests significant social and economic differences within and between archaeological sites of virtually every period[1],

[1] The lack of any context for cultural and historical time is yet another problem frequently associated with GIS analyses of archaeological data (Gaffney 1995). Most GIS applications and conventional mapping methods impose a two-dimensional abstraction of reality, seriously constraining one's ability to analyze and represent time and depth (Harris 2002). For the most part, in GIS the data are represented by time slice

many GIS applications represent the data as a series of bland egalitarian symbols. Kamermans (2000:124) sums up this very succinctly when he states that GIS predictive models fail to make “distinctions between archaeological time periods, economic systems and the difference in types of find spots.” To illustrate: different economic systems have different requirements of the landscape. One can expect a relationship between soil type and Neolithic farming but it is less obvious between soil type and Paleolithic hunter-gatherers for whom a relationship between geomorphology and site location is more likely (Kamermans 2000). Lumping all archaeological find spots together means lumping different economic systems together (Kamermans 2000). The same argument holds for different types of find spots. Habitation sites and burial sites, for example, do not necessarily have the same requirements of the landscape (Kamermans 2000). Failing to recognize these differences results in a significant coarsening of the resolution of the archaeological data in GIS data models, which in turn lends itself to very crude analyses. According to Gaffney (1995) this practice is reflected in the current emphasis on the locational and point analysis of sites within many GIS studies (Gaffney 1995).

Environmental variables are often considered by archaeologists to be important in conditioning the choice of activity locations in the pre-Columbian past (Dalla Bona 2000:75). However, it is possible people may search only for a few cues in their surroundings (when identifying and selecting activity locations), rather than processing

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and in isolation from what has gone before or what comes afterwards. This is a very artificial situation as few cultures have the luxury of arriving first on any landscape (Gaffney 1995). The apparent isolation of settlement systems in time and space gives the impression that choice is unconstrained, except by environmental and economic factors (Gaffney 1995). However, according to Knowles (2002) archaeologists have usually dealt with the problem of time and depth in GIS applications by stacking vertical layers of two-dimensional distribution maps. Most historical GIS has incorporated time simply as one of the many fields in the attribute database, where it can be used to examine distribution patterns based on a specified date or period (Knowles 20002).

the entire range of environmental "cues" available (Dalla Bona 2000:75). Indeed, Kohler and Parker (1986:433) argue that in building predictive models, we are often too eager to make the assumption that only a complex mutivariate model can easily account for human locational behavior, when in fact, a few (proxy?) variables, observed in the highly correlated database that is in our environment, may be sufficient for forming locational decisions.

The promotion, development, and application of GIS predictive modeling as a cultural resource management tool should be tempered by the following concerns. First, as many researchers working with recorded site files can attest, there are often problems with the accuracy and completeness of data regarding site locations and cultural information (Duncan and Beckman 2000:55). Inaccuracies in site location or extent may lead to erroneous environmental correlations. In addition, the site record is a highly biased sample of site distribution across the landscape, both in methodology and documentation (Duncan and Beckman 2000:55). When attempts are made to determine areas of relative probability for site locations, the lack of sufficient and reliable data ultimately controls the modeler's ability to create an effective inductive model. However, Kvamme (1988) correctly asserts that in all cases the bias and insufficiency of the known site record is an inherent and pervasive problem that is difficult to overcome.

Another consideration is the nature of the environmental data set. The modeling process assumes that the attractiveness of the land parcels in the past can be related either directly or indirectly, to currently measurable modern characteristics across the landscape (Duncan and Beckman 2000:55). This assumption may be faulty, and at times directly misleading. For instance, in the search for statistical relationships between sites and

environmental variables within the Monongahela River Valley study area (Pennslyvania), no statistical correlation was found between site locations and the existence of springs a nearby water source (see Duncan and Beckman 2000:33-58). Closer examination of the data sets determined that a number of factors contributed to this incongruity, including the fact that disturbance and/or development may have obliterated the location of springs; that springs are not consistently mapped features; that changes in the water table may have occurred; and that the areas which do have mapped springs tend to be those which have not been seriously investigated/documented by archaeologists (see Duncan and Beckman 2000:55).

**Visibility Models: An Alternative GIS-Based Approach to Settlement Patterns**

The alternative view to GIS predictive modeling demands that we acknowledge that human actions to material situations are culturally mediated and that we approach regularities in the archaeological record, not from the perspective which views pattern as a direct response to stimuli, but which interprets change and patterns within a historically specific context (Barrett 1993:165). This view is encouraged by Renfrew's (1982:11) suggestion that "if people's actions are systematically patterned by their beliefs, the patterning (if not their beliefs, as such) can become embodied in the archaeological record."

Gaffney et al. (1995) argue that although using GIS to analyze mapped data is one of the strengths of the technology, the exclusive application of GIS techniques in such a way could ultimately prove to be restrictive to the general development of archaeological thought. In its least harmful form, the indiscriminate use of GIS solely in conjunction with mapped physical data may result in the slick, but repetitious, confirmation of

otherwise exposition of otherwise obvious relationships (Gaffney et al. 1995:211). In the worst case, it might involve the unwitting exposition of an environmentally or functionally deterministic analytical viewpoint of a type that has largely been rejected by the archaeological community (Wheatley 1993). As a counterbalance to these approaches (which seem to be inherent in GIS predictive models), what is beginning to emerge as a strong theme within Europe are efforts to move beyond environmental determinism by aspiring towards to representations of social landscapes and associated landscapes[2] (Harris and Lock 1995:355). The seeds of this approach were sown by the publication of the first European GIS landscape analysis (Gaffney and Stančič 1991) and reactions to it. Attempts at developing new analyses center around the use of viewshed analysis and multiple viewsheds (Ruggles et al. 1993; Wheatley 1993; Gaffney et al. 1995).

As indicated by Knowles (2002:196) viewshed analysis is a method of spatial analysis that calculates and displays in map form which areas are visible and which are not from a specified x,y,z position. Essentially, it enables one to simulate the effect of standing at any point in the landscape and seeing what one actually sees from that location (Harris 2002:133). Viewshed analysis was used to examine the significance of long barrows, one of the few kinds of evidence that survives from the Neolithic period in the Danebury area in Western Europe (Harris 2002:134). Long barrows were known to

[2] In many ways, the concerns of GIS-based CRM in North America and in Europe represent a continuation of pre-existing areas of interest. North American CRM has a long-standing focus on the predictive modeling of site location. The early interest of much GIS work in the United States has thus been to emulate and pursue this long-standing research theme. European concerns within CRM have centered more on modeling the structure of the cultural landscape and with the related issues of data structure and spatial and temporal definitions of sites (Lang and Stead 1992). The difference between European and North American archaeological traditions has its origins in the physical characteristics of the archaeological record in the two continents. Compared to North America, European archaeology is temporally and spatially rich and creates a much denser and more complex cultural landscape to record and manage. These differing areas of emphasis result in North American CRM having closer links with the spatial statistics tradition whereas European CRM is associated more with landscape tradition (Harris and Lock 1995:353).

be funerary monuments – larger versions of round barrows – as well as being territorial markers dominating a specific landscape. Harris (2002:134) argues that this interpretation was supported by the fact that some barrows contain no human remains, and the visual dominance of a long barrow over a particular area was interpreted as representing the demarcation of a prehistoric group's social and political territory. His viewshed analysis therefore confirmed that barrows could indeed have served as territorial markers, for some barrows came into view as one crossed a ridgeline (Harris 2002:134). The second case study relates to the island of Hvar off the coast of central Dalmatia, Croatia (Gaffney et al. 1995:213-219). GIS cost surface catchments for each hillfort at Hvar were constructed using a timed and measured journey across the Stari Grad plain as a calibration factor. The results suggested that these sites might be interpreted as the central places of small prehistoric communities and that they were situated in order to control large expanses of fertile land (Gaffney et al. 1995:215).

Wheatley and Gillings (2000:1) argue that the application of visibility and viewshed analyses have become the frequently cited response to those who question whether GIS represents a true methodological advance, or simply increased efficiency in the spreading of dots across maps. The suggestion is that through viewshed analysis GIS can make its most unique and valuable contribution to landscape study. Despite this, the extent to which viewshed analyses truly represent a marked departure from environmental determinism has been seriously challenged. Martin van Leusen (1995) believes that these "cognitive models" in GIS applications are no different from the environmental deterministic approach, in that they still involve measurable properties of the environment such as DEM, friction surfaces, slope and vegetation cover. Given these

realities, Martin van Leusen (1995) argues that visibility models are limited in exactly the same ways the environmental deterministic models are limited.

**Critique of Visibility and Viewshed GIS Models**

In addition, whilst GIS-based approaches to visibility have been highlighted as a dramatic methodological advancement, it should be acknowledged that the solution offered by the GIS to the problem of how to quantify and represent visibility mirrors precisely that adopted by archaeologists in the 1970s (Wheatley and Gillings 2000). Like GIS-based solutions, these were based on the measurement and analysis of line-of-sight (intervisibility) and field or view (viewshed) elements. In other words, the GIS-based analyses of visibility currently being developed are not "new" in any theoretical sense (Wheatley and Gillings 2000).

Nor should it be assumed that GIS visibility models are entirely bereft of inherent biases, which can produce skewed results. Any formal analysis of visibility undertaken in GIS is predicated upon the prior existence of a Digital Elevation Model (DEM) or Digital Terrain Model (DTM). However, the issue of DEM error, its representation and propagation can produce skewed results. Fisher (1993:331-347), for example, has shown that variations in the algorithm chosen to derive a given viewshed can result in significant differences in the final form of the mapped field-of-view. In a study of the algorithms implemented within different GIS packages, Fisher found variations of up to 50% in the area of a given viewshed, caused by differences in the way in which different implementations determined factors such as the method used to infer elevation for the DEM, how viewer and target locations are specified and treated, and how elevations are compared between locations on DEM (see Wheatley and Gillings 2000:10).

Edge effects constitute another important factor in the interpretation of viewshed and visibility patterns (Van Leusen 1999). Since viewsheds are generally very large relative to the study region, they tend to "fall off the edge" of the study area. As a result a degree of caution must be exercised in the interpretation of apparent visibility patterns (Wheatley and Gillings 2000:11). It has also been pointed out that in GIS-based archaeological studies purporting to be analytical, little quantitative rigor is exercised in assessing the validity of claims based upon the study of viewsheds. As indicated by Aldenderfer (1996:16), the study of multiple viewsheds "could" be seen as a form of exploratory data analysis, but more often "the calculation of viewsheds can be used in lieu of thinking about the problem." An exception has been the work of Wheatley (1995:171-186) on the analysis of cumulative viewsheds. These summed viewsheds can be treated as a statistical population of the number of visible sites of all the cell locations in the study area, and the individual sites as samples of this population. As a result one-sample statistical tests can be undertaken comparing the site intervisibility data against a background standard (see Wheatley and Gillings 2000:11).

Many of the major works in line-of-sight GIS applications clearly ignore the presence of vegetation (Wheatly and Gillings 2000). By assuming that plant life has no, or at best only a trivial, impact on the overall outcome of a viewshed analysis is to reduce the means of human perception solely to the capacity of sight. Viewsheds without vegetation characteristics will, therefore, more often than not, merely reflect the physical shape of the surface and not access the more rewarding detailed information that could be extracted as part of the wider landscape context (Tschan et al. 2000:34). These "barren

landscape" approaches are also particularly problematic when there is an obvious chance that in the past the vegetation clearly played an important role (Tschan et al. 2000:35)[3].

**Conclusion**

Despite spirited attempts by post-processual archaeologists to portray GIS visibility and viewshed analyses as superior to GIS predictive models are simply indefensible. Despite charges of environmental and functional determinism that have repeatedly been leveled against predictive modeling, the nature and scope of GIS models, whether predictive or visibility, are heavily skewed towards environmental features and processes. Therefore, rather than attempting to give the false impression that GIS visibility models are less environmentally deterministic than predictive models, researchers should instead gratefully acknowledge the quintessential value of GIS in analyzing environmental features and seek to apply the technique both in a self-reflexive and critical manner. GIS-based predictive modeling in settlement archaeology should therefore not be summarily dismissed as environmentally deterministic as this method can (a) enhance our understanding of the relationship between settlement sites and their environmental correlates and (b) provide important clues concerning where sites are likely to be found (Wescott and Brandon 2000).

It is important to recognize that while representing "sites" and "nonsites" as land parcels may be more suitable for logistic regression analysis, the representation of sites as training points is more appropriate in the application of the weights of evidence method, which determines the predictive strength of environmental features such as soil texture, land capability, and relief on the basis of the areal association between the training points

[3] The reconstruction of past vegetation patterns in relation to viewshed models of early Holocene Wrzesnica (Poland) is a major exception (Tschan et al. 2000)

and environmental data (Bonham-Carter 1992). Because the weights of evidence method allows certain variables to have more "predictive strength" than other variables, it results in a model that better reflects the decisions made by prehistoric people when choosing their activity areas. In light of these considerations, weights of evidence will be judiciously used in this study to create predictive models with a view towards enhancing cultural resource management of Trinidad's pre-Columbian settlement sites.

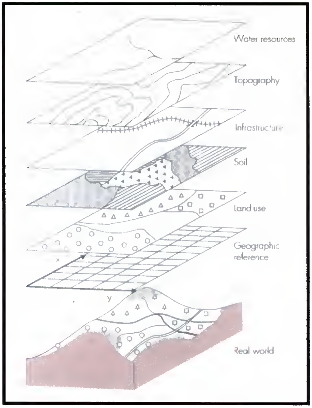


Figure 4-1. Diagram depicts the various theme layers in GIS, with each layer linked to a common georeferencing system. (Source: *Geographic Information Systems: An Introduction* by Tor Bernhardsen p. 6, [Second Edition; John Wiley & Sons, Inc.]).

# CHAPTER 5
# METHODOLOGY

Weights of evidence modeling for the watersheds of South Oropouche, Pilote, Cipero and Rest North was applied in six steps: (1) selection of a descriptive model (2) selection of exploration (evidence) themes based on the descriptive model (3) refining the descriptive model based on the exploration (evidence) themes (4) selection of a training set (5) testing of the exploration themes to qualify them as viable (predictor) themes and (6) consolidating the themes into archaeological site location predictive models. A generalized flow chart of these procedures is depicted as Figure 5-1.

The analysis was accomplished on a personal computer using an ArcView GIS v. 3.1 platform with Spatial Analyst v. 1.1 and Weights of Evidence software. The assessment method required that all the data be analyzed in digital form. At least 20 person days were expended by the author (between October and December 2002) to prepare training points, test exploration themes and produce response themes for all the selected watersheds. Analyzing response themes, unique conditions tables, posterior probability maps and other related weights of evidence outputs required an additional 10 person days.

## Selection of a Descriptive Model

The descriptive model is premised on the assumption that pre-Columbian settlement patterns in Trinidad and elsewhere in the Caribbean are determined by the following factors:

(1) **Landform** (2) **Relief**. Irrespective of whether they are inland or coastal sites, a significant number of pre-Columbian sites in the Trinidad and elsewhere in the Caribbean tend to be situated on low lying hills or knolls (see Allsworth-Jones et al. 1999; Curet 1992). The reasons for this are unclear but defense and health considerations have been cited (Howard 1965).

(3) **Land capability** (4) **Soil texture**. Given their impact on land productivity, these factors would be especially germane to horticultural peoples such as the Saladoid and Guayabitoid (see Boomert 2000; Roosevelt 1997).

Hence, the following generalized descriptive model was devised:

<u>Pre-Columbian sites in Trinidad are likely to be found on landforms with higher relief, and in areas with favourable land capability and soil texture.</u>

This descriptive model was subsequently refined after the evidential themes were selected and analyzed.

### Selection of Exploration (Evidence) Themes Based on the Descriptive Model

The evidential themes of Landform, Relief, Land Capability and Soil Texture, selected for this study, are a collection of vector data sets on Trinidad generated by the Survey and Land Information Department of the University of the West Indies, St. Augustine, Trinidad and Tobago. Originally digitized from a hard copy soils map of Trinidad (with a scale 1:150,000), the GIS data were produced in the 1990s and georeferenced in UTM coordinates 20N (Naparima 1955).

### Refining the Descriptive Model

The disparate collection of class descriptions within the GIS evidential themes posed a considerable challenge. Relief descriptions of Trinidad are not quantitative but are loosely categorized as “flat,” “low undulating hills,” “rolling hills,” “slightly undulating hills,” “hilly,” “gently slopes from hills,” “hilly with mild slopes” and “hilly with steep slopes.” The selected watersheds lie within the physiographic zones of the

Southern Lowlands and the Southern Range - areas with either flat or gently rolling landscapes with the highest point being Trinity Hill at 303 m above MSL. Consequently, it was decided that the most effective way of circumnavigating this problem was simply to place the various "hill-related descriptions" within the general category of "hilly" and refer to the remaining descriptions as "flat." Given the propensities of pre-Columbian peoples in the Caribbean, the "hilly" nomenclature was considered more appropriate for the refined descriptive model.

The evidential theme of Landform was less problematic as it only contains three major classes: (1) Alluvial Plains and Valleys (2) Terraces and (3) Uplands. Several pre-Columbian communities, especially in the larger Caribbean islands, such as Jamaica, Puerto Rico, Hispaniola and Cuba are primarily concentrated in alluvial plains and valleys (Curet 1992; Rouse 1992). This nomenclature was therefore selected for the refined descriptive model.

Seven major classes constitute the Land Capability theme: (1) very good land that can be easily cultivated (2) very good land, easily cultivated, simply protective measures required (3) good land, requires moderate to intensive conservation and management (4) moderately good land requires intensive conservation and management (5) fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope (6) unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest and (7) unsuitable for agriculture due to very steep slopes, should be left under indigenous growth or forest. Land Capability classification is a system of grouping soils primarily on the basis of their capability to produce common cultivated crops without deteriorating over a long period of time. Despite the fact that

Land Capability classifications were crafted within the context of contemporary soil conditions in Trinidad; for heuristic purposes, it was decided to use these taxonomies in relation to pre-Columbian settlement sites. Given the importance of high land productivity among prehistoric horticultural groups, the Land Capability descriptions of "very good land," "good land" and "moderately good land" were viewed as perhaps the most relevant for the refined descriptive model.

The relative proportion of sand, silt and clay found in a given soil determines soil texture. Similar to the Relief theme, the Soil Texture theme of Trinidad has a diverse collection of classes, which for the purposes of a descriptive model required some level of rough categorization. The classes are as follows: "sandy clay," "clay loam," "sand," "sandy loam," "loamy fine sand," "fine sandy loam," "gravelly sandy clay," "peaty clay" and "clay." Root crop agriculture, based on the cultivation of manioc, sweet potatoes and to a lesser extent maize, was a defining characteristic of prehistoric societies in the Lowland American Tropics (Lathrap 1970; Roosevelt 1980). While little is known about the lifeways of the pre-Columbian horticultural settlers of Trinidad, it is highly likely that Saladoid and Guayabitoid migrants from South America extended their root crop agricultural practices to Trinidad (Boomert 2000). Manioc, sweet potatoes and corn generally thrive well in "free internal drainage" soils such as "sandy clay," "sand," "sandy loam," "loamy fine sand," and "fine sandy loam" (Farmer's Book Shelf 2002). However, these cultigens are not as successful in "restricted internal drainage soils" such as "clay" and "peaty clay." Therefore, on purely commonsensical grounds, the nomenclature "free internal drainage soils" was incorporated into the refined descriptive model.

Hence, the refined descriptive model for the selected watersheds reads as follows:

Pre-Columbian sites in Trinidad are likely to found in areas with hilly relief in alluvial plains and valleys, in areas with very good to moderately good land capability and free internal drainage soils.

In Chapter 6, this model will be compared with the results of the weights of evidence analysis.

**Selection of Training Set**

The training points used to test the refined descriptive model are all the known Archaic, Saladoid and Guayabitoid sites within the selected watersheds. Mayoid sites were not used as training points as with the exception of Guayaguayare, they are contact period sites, not pre-Columbian. The Ortoiroid or Archaic peoples of Trinidad were foragers not horticulturalists (Boomert 2000; Keegan 1994). Conceivably therefore, their settlement sites would have been more heavily determined by landform and relief rather than soil texture and land capability. However, South Oropouche is the only selected watershed with a smattering of Archaic sites as the remaining watersheds exclusively contain Saladoid and/or Guayabitoid sites. Archaic sites were included in the South Oropouche watershed in order to create a more robust predictive model for that region of interest.

Archaeological site data were extracted from a compilation of site files[1] in Microsoft Excel. The latter were converted into DBF files, imported to ArcView GIS as event themes (based on their Northing and Easting coordinates) and subsequently converted to shape files in ArcView. A list of the pre-Columbian sites in Trinidad is at

[1] These files are the product of 22 years of site inventory carried out in Trinidad by Arie Boomert, Peter Harris and Nicholas Saunders.

Table 5-1. Tables 5-2 to 5-5 list the specific sites that were used in relation to the selected watersheds.

**Testing of the Exploration Themes to Qualify Them as Viable (Predictor) Themes**

In step 5, the testing process consisted of digitally comparing the areal (or spatial) distribution of training set with evidential themes. Prior to getting to this stage, however, several preliminary operations in ArcView GIS were required. First, the watersheds of South Oropouche, Rest North, Pilote and Cipero were individually clipped from the Trinidad watershed theme. The watersheds were subsequently clipped from the "Landform," "Soil Texture," "Land Capability," "Relief" and "Pre-Columbian Sites" evidential themes. This was designed to enable efficient processing of only those areas that fell within the physical parameters of the watersheds.

In ArcView Spatial Data Modeler (SDM), the study area is an integer grid theme that defines the regions of interest. It acts a mask on areas of evidential themes and, if they are being used, training points outside the study area are ignored during processing. In order to create study areas for each selected watershed, individual watershed shape files were converted to grid themes each with 500-cell grid size. This grid cell size spatial resolution was selected, as it was not considered too fine-grained or too coarse grained[2]. Next, using Spatial Data Modeler in ArcView, Analysis Parameters were set for each of the selected watersheds. The details are in Table 5-6.

The weights of each evidential theme of the selected watersheds were then calculated as "free" or "categorical" data. Testing produced weights, contrast, and other statistical values calculated for each of the various comparisons. The weights (positive

[2] The finer grained resolution requires longer processing time but produces more details. The coarser grained resolution requires shorter processing time but produces fewer details.

weight W+, negative weight, W-) express the degree of spatial association between the training set and the evidential themes. Tables and charts depicting output weights of the Landform, Relief, Soil Texture and Land Capability are shown as Tables 5-7 - 5-22 and Figures 5-2 - 5-17.

The contrast values of the various classes within Tables 5-7 - 5-22 and Figures 5-2 - 5-17 were used as the basis for accepting and rejecting particular evidential for the predictive models. The following rule of thumb for interpreting contrast values for predictor themes was applied (see Bonham-Carter 1994):

| If contrast value is: | Level of prediction is: |
|---|---|
| 0 - 0.5 | Mildly |
| 0.5 - 1 | Moderately |
| 1 - 2 | Strongly |
| >2 | Extremely |

A decision was made to select only those contrast values above 0.5 as values below this threshold (as is the case with Table 5-21/ Figure 5-16, class 7 and Table 5-22/ Figure 5-17, class 17) were not considered significant enough to produce optimal results. The 0 Classes of Table 5-7/ Figure 5-2, Table 5-8/ Figure 5-3, Table 5-9/ Figure 5-4, Table 5-18/ Figure 5-13 and Table 5-22/ Figure 5-17 all bear contrast values above 0.5 but were rejected as the 0 represents "data not given" or "missing data." All the classes within the various watershed themes, whose contrast values have been highlighted in Tables 5-7 - 5-22, were in fact selected for the weights of evidence predictive models.

With respect to Cipero, the evidential theme of Soil Texture was completely bereft of positive contrast values (Table 5-8, Figure 5-3). Hence, Soil Texture was eliminated from this watershed's predictive model. The predictive model for Cipero was therefore based on the following:

1. Evidential Theme: **Landform** /Class Identifier: **3** /Class Descriptor: **Uplands**

2. Evidential Theme: **Land Capability** / Class Identifier: **6** / Class Descriptor: **Unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest.**

3. Evidential Theme: **Relief** / Class Identifier: **17** / Class Descriptor: **Rolling**

The following evidential themes comprised Pilote's predictive model:

1. Evidential Theme: **Landform** /Class Identifier: **1** /Class Descriptor: Alluvial Plains and Valleys

2. Evidential Theme: **Soil Texture** / Class Identifier(s): **8,12** / Class Descriptor(s): **Loamy Sand, Sand**

3. Evidential Theme: **Land Capability** / Class Identifier(s): **4** / Class Descriptor: **Moderately good land**

4. Evidential Theme: **Relief** / Class Identifier: **1** / Class Descriptor: **Flat**

With respect to South Oropouche, the Soil Texture evidential theme (Table 5-16/ Figure 5-11) failed to generate any weights or contrasts, hence it was eliminated from this watershed's predictive model. South Oropouche's predictive model was therefore based on the following:

1. Evidential Theme: **Landform** / Class identifier: **3** / Class Descriptor: **Uplands**

2. Evidential Theme: **Land Capability** / Class Identifier: **6** / Class Descriptor: **Unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest**

3. Evidential Theme: **Relief** / Class Identifier: **17** / Class Descriptor: **Rolling**

Rest North's predictive model was based on the following:

1. Evidential Theme: **Landform** / Class Identifier: **1** / Class Descriptor: **Alluvial Plains and Valleys**

2. Evidential Theme: **Soil Texture /** Class Identifier(s): **2,3** / Class Descriptor(s): **Clay Loam/ Fine sandy Clay**

3. Evidential Theme: **Land Capability** / Class identifier: **5** / Class Descriptor: **Fairly good land**

4. Evidential Theme: **Relief** / Class Identifier: **1** / Class Descriptor: **Flat.**

**Generalization of Evidential Themes**

Prior to creating a unique conditions table and a response theme, all the selected evidential themes were generalized or "reclassified." By using the "group classes classification" tool, the current classes were converted into the binary class of 1 (those not selected for the predictive models) and 2 (those selected for the predictive models). Once specified, the new classes were appended to the evidential themes' attribute tables as Landform_2, Texture_2, Capability_2 and Relief_2. For example, class 6 in South Oropouche's Land Capability evidential theme was reclassified as 2 while the remaining classes in that theme were reclassified as 1. With regard to the Pilote watershed, the class descriptors of loamy sand and sand (8 and 12 respectively) were both reclassified as 2 (given their similar soil constituents and their classification in the refined descriptive model as "free internal drainage soils"). However, Rest North's Soil Texture evidential theme contained two very different selected classes: clay loam and fine sandy clay (2 and 3 respectively). Based on the refined descriptive model, "clay loam" is considered a "restricted internal drainage soil" while "fine sandy clay" is generally regarded as a "free internal drainage soil." Therefore, the two classes were not combined and reclassified as 2. Rather, a new class descriptor named "Texture_3" for created for "fine sandy clay" while "Texture_2" was ascribed to clay loam. As part of the response theme calculations, the two classes were subsequently run as conditionally independent entities.

**Consolidating the Themes into Archaeological Site Location Predictive Models**

After generalization, the selected themes were combined by generating a unique conditions grid and attribute table. The weights of evidence tool calculated the posterior probability, normalized probability, sum of weights, uncertainty due to weights, uncertainty due to missing data and the total uncertainty and join these statistics to the attribute table of the unique conditions grid.

Tables 5-23 - 5-38 depict the various data outputs generated by weights of evidence analysis, such as weights of evidence, attributes of response themes, posterior probability and conditional independence. Layouts showing the posterior probability results of all four watersheds are shown as Figures 5-18 - 5-21. In order to create predictive models showing areas of "high," "moderate" and "low" archaeological site location favorability, the posterior probability results of the various watersheds (Tables 5-25, 5-33 and 5-37) were ranked. Essentially, the prior probability of each watershed was used as the threshold between "low" and "moderate" favorability (see Boleneus et al. 2001:31) while the highest posterior value was used as the threshold between "moderate" and "low" favorability. These unique values were subsequently reclassified in ArcView as follows: 1 for "low" favorability, 2 for "moderate" favorability and 3 for "high" favorability. The Pilote watershed was not selected for reclassification, as its very poor conditional independence results (Table 5-30) cast serious doubts on the reliability of its weights of evidence results (Tables 5-28 and 5-29).

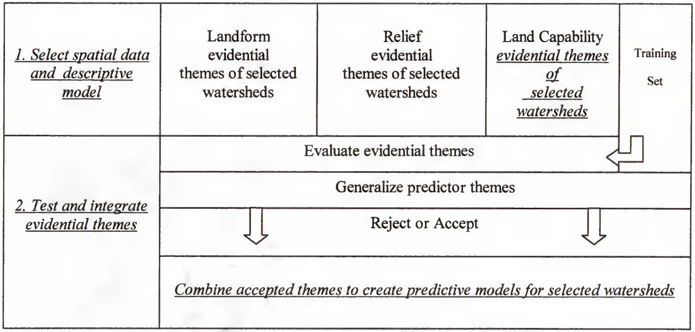


Figure 5-1. Flow Diagram Describing Procedures in Weights of Evidence Modeling.

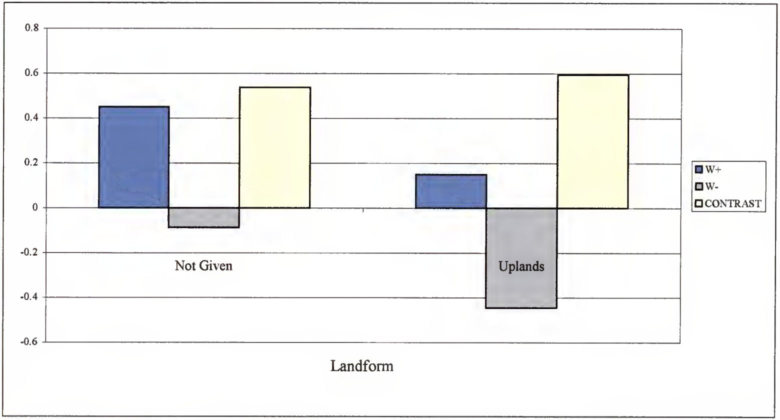


Figure 5-2 Output Weights Table of Landform Evidential Theme (Cipero Watershed)

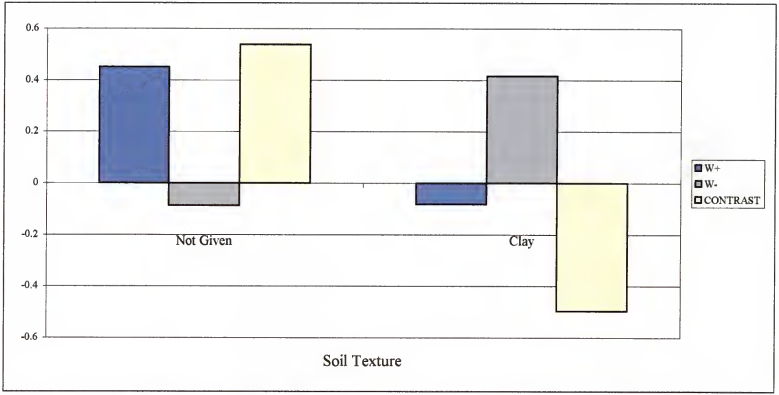


Figure 5-3 Output Weights Table of Soil Texture Evidential Theme (Cipero Watershed)

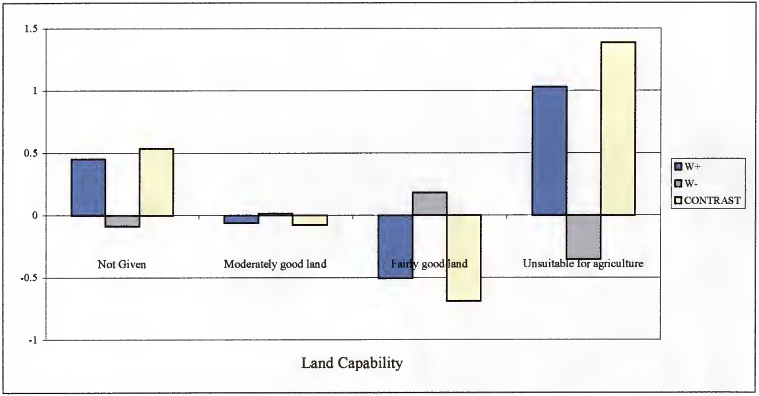


Figure 5-4 Output Weights Table of Land Capability (Cipero Watershed)

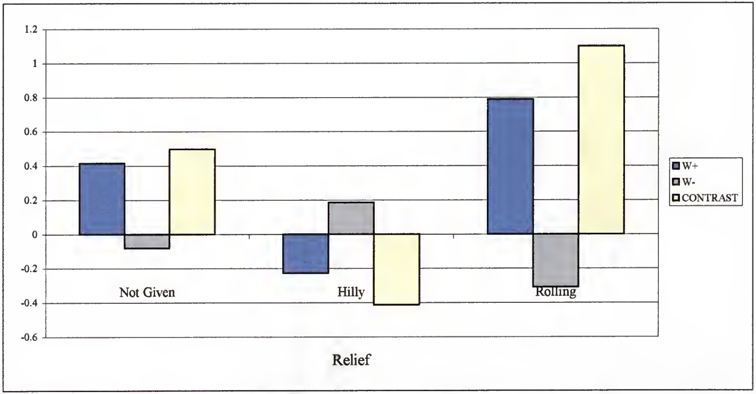


Figure 5-5 Output Weights Table of Relief Evidential Theme (Cipero Watershed)


Figure 5-6 Output Weights Table of Landform Evidential Theme (Pilote Watershed)

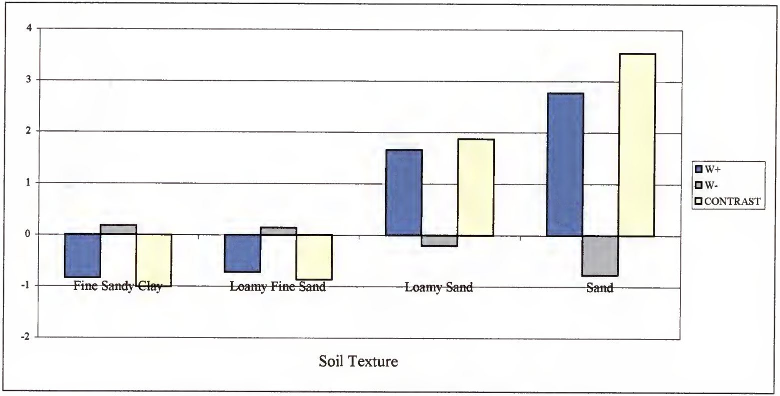


Figure 5-7 Output Weights Table of Soil Texture Evidential Theme (Pilote Watershed)

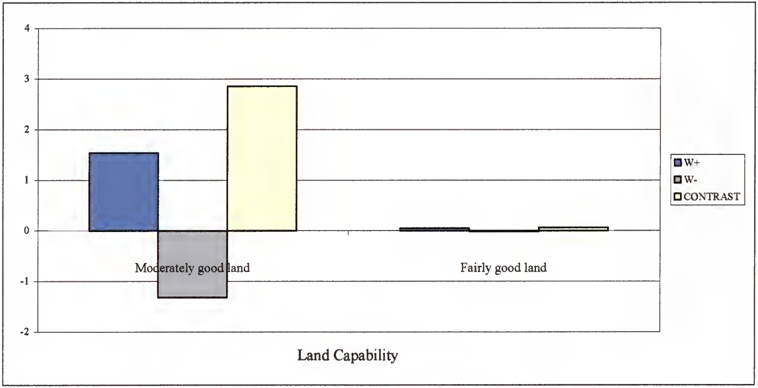


Figure 5-8 Output Weights Table of Land Capability (Pilote Watershed)

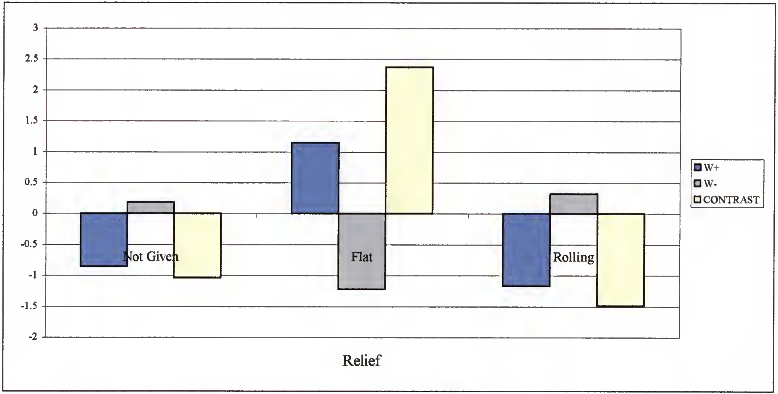


Figure 5-9 Output Weights Table of Relief Evidential Theme (Pilote Watershed)

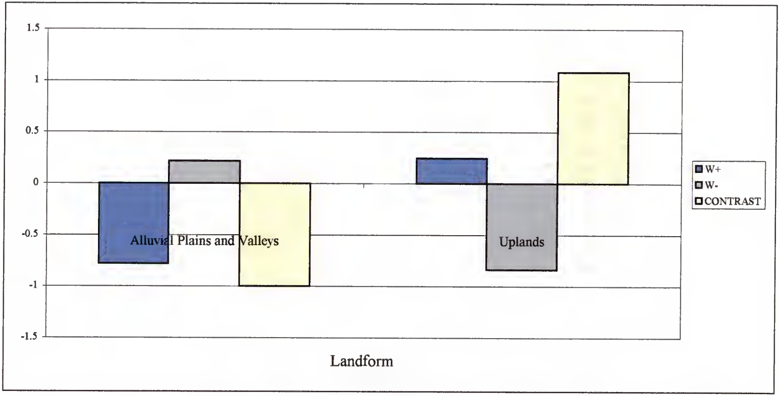


Figure 5-10 Output Weights Table of Landform Evidential Theme (South Oropouche Watershed)

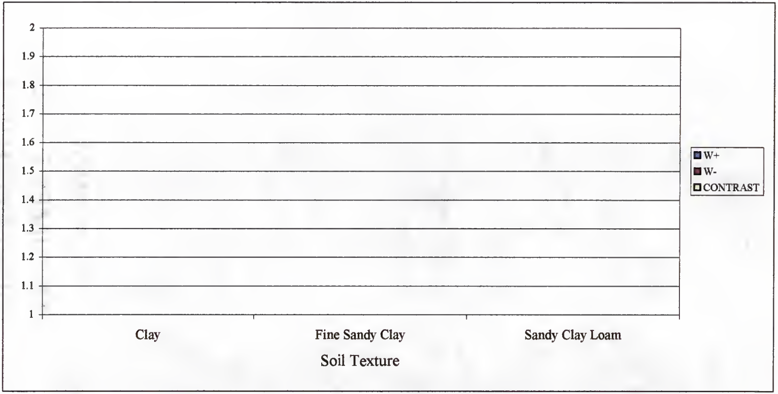


Figure 5-11 Output Weights Table of Soil Texture Evidential Theme (South Oropouche Watershed)

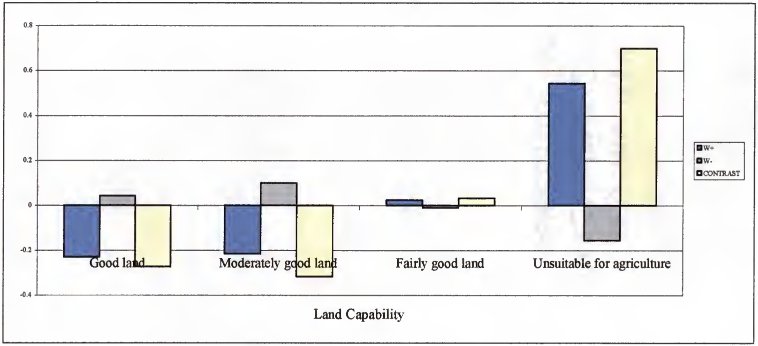


Figure 5-12 Output Weights Table of Land Capability (South Oropouche Watershed)

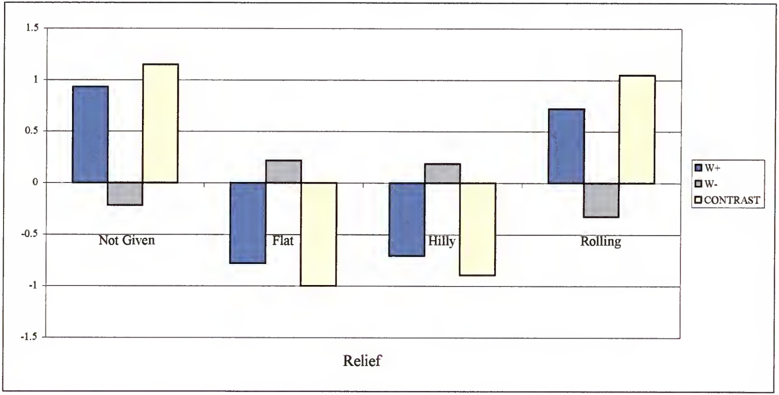


Figure 5-13 Output Weights Table of Relief Evidential Theme (South Oropouche Watershed)

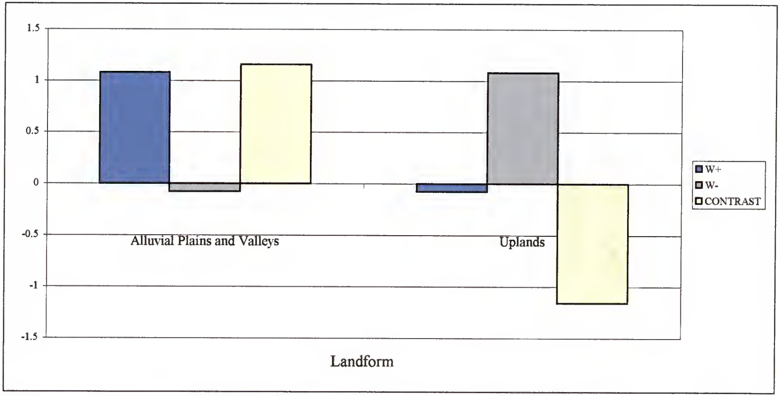


Figure 5-14 Output Weights Table of Landform Evidential Theme (Rest North Watershed)

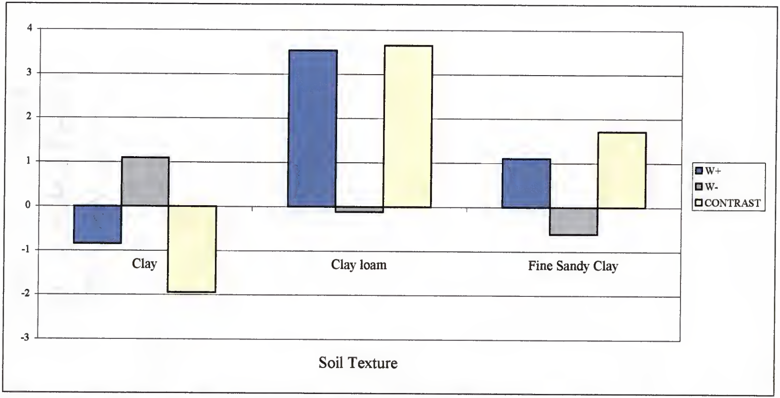


Figure 5-15 Output Weights Table of Soil Texture Evidential Theme (Rest North Watershed)

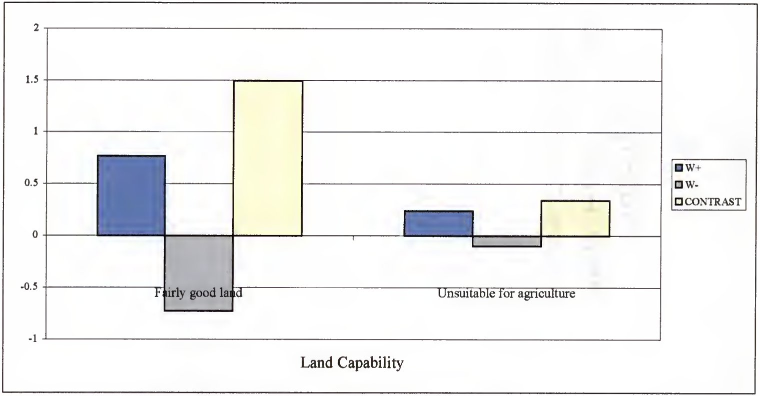


Figure 5-16 Output Weights Table of Land Capability (Rest North Watershed)

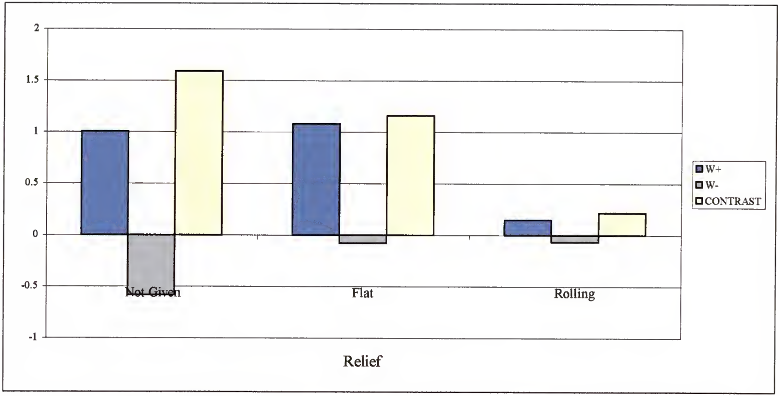


Figure 5-17 Output Weights Table of Relief Evidential Theme (Rest North Watershed)

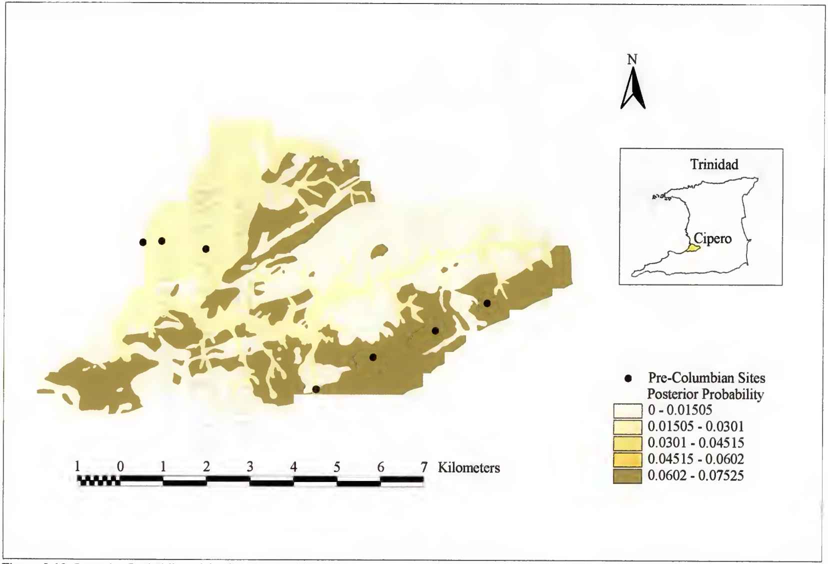


Figure 5-18 Posterior Probablity of the Cipero Watershed

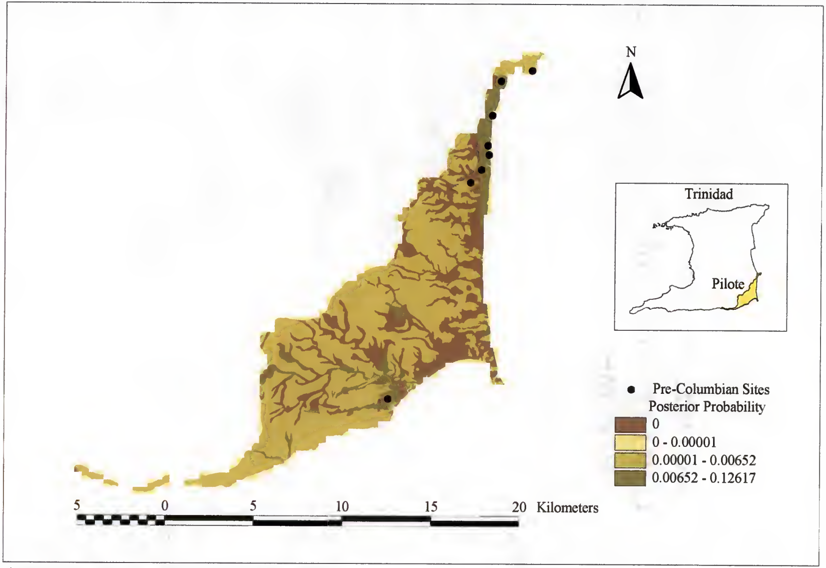


Figure 5-19 Posterior Probability of the Pilote Watershed

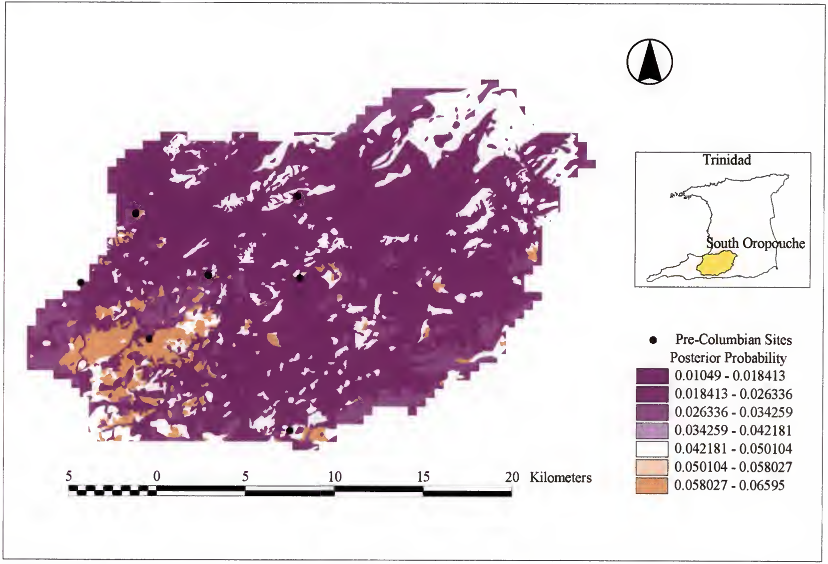


Figure 5-20 Posterior Probability of the South Oropouche Watershed

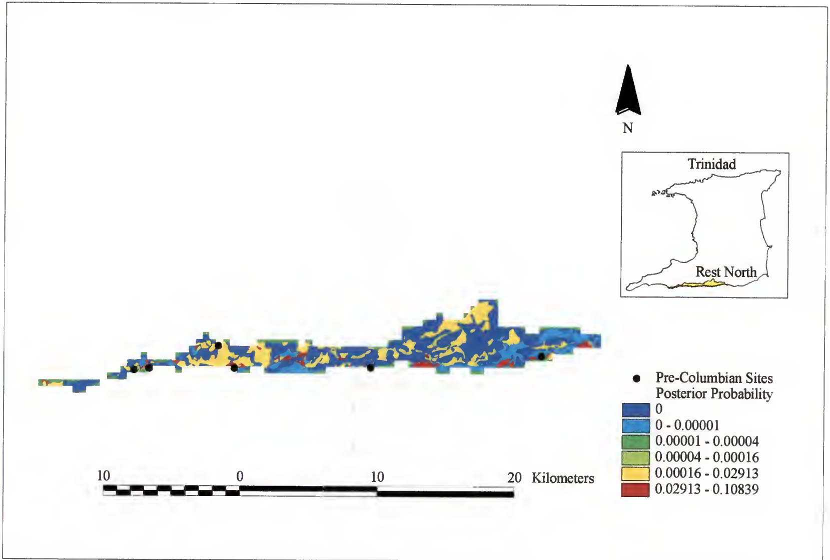


Figure 5-21 Posterior Probablity of the Rest North Watershed

Table 5-1. List of Pre-Columbian Sites in Trinidad.

| SITE_CODE | COUNTY | SITE NAME | EASTING | NORTHING |
|---|---|---|---|---|
| SGE16 | St George | St.Joseph2 | 673320 | 1178120 |
| SDA1 | St.David | Sans Souci | 717350 | 1198925 |
| San2 | St.Andrew | N.Manzanilla1 | 717150 | 1164850 |
| San7 | St.Andrew | Brigand Hill | 710525 | 1160550 |
| Nar6 | Nariva | Siewdath Trace | 717225 | 1142000 |
| Car6 | Caroni | San Pedro Estate | 676688 | 1149125 |
| 1-May | Mayaro | Point Radix1 | 721750 | 1142375 |
| 3-May | Mayaro | Lagon Doux | 717650 | 1134800 |
| 5-May | Mayaro | Rest House | 719463 | 1140438 |
| 6-May | Mayaro | Beausejour | 719100 | 1139360 |
| 7-May | Mayaro | St.Ann's Road1 | 718800 | 1137325 |
| 8-May | Mayaro | Beggorat | 718900 | 1136700 |
| 16-May | Mayaro | Guayaguayare | 712500 | 1119225 |
| 17-May | Mayaro | St.Catherine's | 712200 | 1120175 |
| 19-May | Mayaro | St.Ann's Road2 | 718825 | 1137075 |
| 20-May | Mayaro | Bon Espoire | 718400 | 1135675 |
| Vic7 | Victoria | La Lune1 | 684100 | 1114600 |
| Vic2 | Victoria | Marac2 | 681170 | 1117098 |
| Vic13 | Victoria | Bontour | 667375 | 1136575 |
| Vic14 | Victoria | San Fernando(H.P/High S | 667825 | 1136600 |
| Vic47 | Victoria | Petite Morne A | 672750 | 1133900 |
| Vic39 | Victoria | Woodlands2 | 674200 | 1134525 |
| Vic20 | Victoria | Picton-Golconda | 671425 | 1133150 |
| Vic1 | Victoria | Table Land | 689700 | 1137850 |
| Vic34 | Victoria | Ben Lomond A | 675500 | 1137950 |
| Vic34 | Victoria | Ben Lomond B | 675575 | 1138450 |
| Vic34 | Victoria | Ben Lomond C | 675575 | 1138325 |
| Vic34 | Victoria | Ben Lomond D | 675450 | 1138200 |
| Vic41 | Victoria | Cedar Hill A | 675400 | 1135175 |
| Vic19 | Victoria | Trinidad Hill | 671400 | 1129475 |
| Spa20 | St.Patrick | Erin | 646875 | 1113700 |
| Spa22 | St.Patrick | Los Iros | 647950 | 1112675 |
| Spa30 | St.Patrick | Palo Seco | 654400 | 1113500 |
| Spa8 | St.Patrick | Palo Seco East | 655525 | 1113625 |
| Spa32 | St.Patrick | Buenos Ayres | 644350 | 1116725 |
| Spa9 | St.Patrick | Chagonaray | 656950 | 1113725 |
| Spa34 | St.Patrick | Carapal | 651200 | 1117035 |
| Spa10 | St.Patrick | Quinam | 661725 | 1113650 |
| Spa23 | St.Patrick | Quinam East | 663975 | 1113475 |
| Spa26 | St.Patrick | Batiment Crase1 | 671650 | 1113725 |
| Spa33 | St.Patrick | Guayabal River | 660550 | 1115300 |
| Spa21 | St.Patrick | Sylvester Trace | 663050 | 1115550 |

Table 5-1. Continued

| SITE_CODE | COUNTY | SITE NAME | EASTING | NORTHING |
|---|---|---|---|---|
| Spa2 | St.Patrick | Siparia | 663075 | 1121350 |
| Spa25 | St.Patrick | Grant's Trace1 | 671025 | 1116200 |
| Spa11 | St.Patrick | St.John(South Oropouche | 662275 | 1128475 |
| Spa19 | St.Patrick | Otaheite | 658775 | 1129700 |
| Spa18 | St.Patrick | Point Fortin2(Hospital) | 644450 | 1124525 |
| Nar3 | Nariva | Cocal1 | 718650 | 1144400 |
| Nar4 | Nariva | Ortoire | 719000 | 1143950 |
| Nar5 | Nariva | Kernahan Trace East &We | 717663 | 1145950 |
| Nar7 | Nariva | Chip Chip Hill | 716250 | 1142200 |
| Car3 | Caroni | Basterhall Reservoir | 670875 | 1149350 |
| Car5 | Caroni | Belle Vue | 670400 | 1147463 |
| Car2 | Caroni | Savaneta1 | 667500 | 1147200 |
| SGE12 | St George | San Juan | 669250 | 1177925 |
| Vic21 | Victoria | Point-a-Pierre1 | 668125 | 1141400 |
| Spa12 | St.Patrick | Columbus Estate | 619500 | 1114225 |
| Spa7 | St.Patrick | Icacos B | 623075 | 1111975 |
| Spa14 | St.Patrick | Lawrence Hill | 671550 | 1124825 |
| Spa11 | St.Patrick | St.John(South Oropouche | 662275 | 1128475 |
| Spa28 | St.Patrick | Banwari Trace | 666400 | 1125000 |
| Spa13 | St.Patrick | Fyzabad | 659175 | 1124550 |
| Spa27 | St.Patrick | Pitch Lake3 | 649975 | 1131875 |
| Spa16 | St.Patrick | Point Fortin1(Golf Cour | 645800 | 1126025 |
| Spa29 | St.Patrick | Parrylands | 651000 | 1125000 |
| Spa3 | St.Patrick | Point D'Or1 | 651800 | 1132950 |
| SGE8 | St George | Blanchisseuse | 685800 | 1193625 |
| SGE10 | St George | Tacarib | 694800 | 1193838 |
| SGE14 | St George | Tacarigua | 678375 | 1177088 |
| SGE31 | St George | Sanders Bay | 636775 | 1181875 |
| SGE17 | St George | Arena Road | 690425 | 1168325 |
| San1 | St.Andrew | Manzanilla1 | 713738 | 1161825 |
| 3-May | Mayaro | Lagon Doux | 717650 | 1134800 |
| 4-May | Mayaro | St Bernard | 719675 | 1141663 |
| 17-May | Mayaro | St.Catherine's | 712200 | 1120175 |
| Vic7 | Victoria | La Lune1 | 684100 | 1114600 |
| Vic15 | Victoria | San Fernando(Carib Street) | 668850 | 1136425 |
| Vic38 | Victoria | Mendoza-La-Gloria | 687025 | 1137700 |
| Vic30 | Victoria | Atagual | 680725 | 1146650 |
| Spa1 | St.Patrick | Cedros | 625500 | 1113000 |
| Spa6 | St.Patrick | Pitch Lake1 | 650450 | 1131425 |
| Spa15 | St.Patrick | Pitch Lake2 | 650325 | 1131200 |
| Vic58 | Victoria | La Fortunee | 664064 | 1130391 |
| Spa24 | St.Patrick | Ramsookie Street(Delhi Rd) | 658091 | 1125933 |

Table 5-1. Continued

| SITE_CODE | COUNTY | SITE NAME | EASTING | NORTHING |
|---|---|---|---|---|
| Spa7 | St.Patrick | Icacos A | 622350 | 1111375 |
| Spa20 | St.Patrick | Erin | 646875 | 1113700 |
| Spa30 | St.Patrick | Palo Seco | 654400 | 1113500 |
| Spa10 | St.Patrick | Quinam | 661725 | 1113650 |

Table 5-2. Sites (Cipero Watershed)

| SITE_CODE | SITE_NAME | EASTING | NORTHING | COUNTY | CULTURAL_P | RANDOM |
|---|---|---|---|---|---|---|
| Vic15 | San Fernando(Carib St) | 668850 | 1136425 | Victoria | Saladoid | 274 |
| Vic13 | Bontour | 667375 | 1136575 | Victoria | Guayabitoid | 907 |
| Vic14 | San Fernando(H.P/High St) | 667825 | 1136600 | Victoria | Guayabitoid | 770 |
| Vic47 | Petite Morne A | 672750 | 1133900 | Victoria | Guayabitoid | 32 |
| Vic39 | Woodlands2 | 674200 | 1134525 | Victoria | Guayabitoid | 254 |
| Vic20 | Picton-Golconda | 671425 | 1133150 | Victoria | Guayabitoid | 401 |
| Vic41 | Cedar Hill A | 675400 | 1135175 | Victoria | Guayabitoid | 581 |

Table 5-3. Sites (Pilote Watershed)

| SITE_CODE | SITE_NAME | EASTING | NORTHING | COUNTY | CULTURAL_P | RANDOM | RECORDID |
|---|---|---|---|---|---|---|---|
| 3-May | Lagon Doux | 717650 | 1134800 | Mayaro | Saladoid | 709 | 0 |
| 4-May | St Bernard | 719675 | 1141663 | Mayaro | Saladoid | 545 | 1 |
| 17-May | St.Catherine's | 712200 | 1120175 | Mayaro | Saladoid | 304 | 2 |
| 1-May | Point Radix1 | 721750 | 1142375 | Mayaro | Guayabitoid | 283 | 3 |
| 3-May | Lagon Doux | 717650 | 1134800 | Mayaro | Guayabitoid | 5 | 4 |
| 5-May | Rest House | 719463 | 1140438 | Mayaro | Guayabitoid | 553 | 0 |
| 6-May | Beausejour | 719100 | 1139360 | Mayaro | Guayabitoid | 93 | 6 |
| 7-May | St.Ann's Road1 | 718800 | 1137325 | Mayaro | Guayabitoid | 431 | 7 |
| 8-May | Beggorat | 718900 | 1136700 | Mayaro | Guayabitoid | 512 | 8 |
| 16-May | Guayaguayare | 712500 | 1119225 | Mayaro | Guayabitoid | 587 | 0 |
| 17-May | St.Catherine's | 712200 | 1120175 | Mayaro | Guayabitoid | 103 | 10 |
| 19-May | St.Ann's Road2 | 718825 | 1137075 | Mayaro | Guayabitoid | 742 | 0 |
| 20-May | Bon Espoire | 718400 | 1135675 | Mayaro | Guayabitoid | 535 | 12 |

Table 5-4. Sites (South Oropouche Watershed)

| SITE_CODE | SITE_NAME | EASTING | NORTHING | COUNTY | CULTURAL_P | RANDOM | RECORDID |
|---|---|---|---|---|---|---|---|
| Spa14 | Lawrence Hill | 671550 | 1124825 | St.Patrick | Ortoiroid | 812 | 0 |
| Spa28 | Banwari Trace | 666400 | 1125000 | St.Patrick | Ortoiroid | 337 | 2 |
| Spa13 | Fyzabad | 659175 | 1124550 | St.Patrick | Ortoiroid | 612 | 3 |
| Vic19 | Trinidad Hill | 671400 | 1129475 | Victoria | Guayabitoid | 575 | 5 |
| Spa2 | Siparia | 663075 | 1121350 | St.Patrick | Guayabitoid | 768 | 7 |
| Spa25 | Grant's Trace1 | 671025 | 1116200 | St.Patrick | Guayabitoid | 219 | 8 |
| Spa11 | St.John | 662275 | 1128475 | St.Patrick | Guayabitoid | 202 | 9 |

Table 5-5. Sites (Rest North Watershed)

| SITE_CODE | SITE_NAME | EASTING | NORTHING | COUNTY | CULTURAL_P | RANDOM | RECORDID |
|---|---|---|---|---|---|---|---|
| Vic7 | La Lune1 | 684100 | 1114600 | Victoria | Saladoid | 237 | 0 |
| Spa30 | Palo Seco | 654400 | 1113500 | St.Patrick | Saladoid/Barrancoid | 880 | 1 |
| Spa10 | Quinam | 661725 | 1113650 | St.Patrick | Saladoid/Barrancoid | 808 | 2 |
| Vic7 | La Lune1 | 684100 | 1114600 | Victoria | Guayabitoid | 704 | 3 |
| Spa30 | Palo Seco | 654400 | 1113500 | St.Patrick | Guayabitoid | 905 | 4 |
| Spa8 | Palo Seco East | 655525 | 1113625 | St.Patrick | Guayabitoid | 499 | 5 |
| Spa10 | Quinam | 661725 | 1113650 | St.Patrick | Guayabitoid | 437 | 6 |
| Spa26 | Batiment Crase1 | 671650 | 1113725 | St.Patrick | Guayabitoid | 203 | 7 |
| Spa33 | Guayabal River | 660550 | 1115300 | St.Patrick | Guayabitoid | 973 | 8 |

Table 5-6. Details of Analysis Parameters of Selected Watersheds.

| Watersheds | Unit Area (sq. km) | Total Study Area (Units) | Total Study Area (sq. km) | Number of Training Points (Sites) | Prior Probability |
|---|---|---|---|---|---|
| Cipero | 0.3 | 165.71 | 49.71 | 5 (70%) | 0.0294 |
| Pilote | 0.4 | 482.11 | 192.84 | 9 (70%) | 0.0184 |
| South Oropouche | 1.6 | 273.92 | 438.27 | 7 (70%) | 0.0256 |
| Rest North | 0.2 | 403.61 | 80.72 | 9 (100%) | 0.0224 |

100% of the Rest North training points were selected, because of the 9 points, only five of the training points lie within the study area. It is important to note that there is no appreciable difference in prior probability and output weights between the application of 100% and 70% of the training set.

Table 5-7. Attributes of Output Weights of Landform Evidential Theme (Cipero)

| CLASS | LFORMDESCP | AREA_KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 6.4422 | 21.4741 | 1 | 0.4510 | -0.0869 | 0.5379 |
| 1 | Alluvial plains and Valleys | 8.8970 | 29.6568 | 0 | | | |
| 3 | Uplands | 34.3740 | 114.5799 | 4 | 0.1507 | -0.4445 | **0.5952** |

Table 5-8. Attributes of Output Weights of Soil Texture Evidential Theme (Cipero)

| CLASS | TEXTURE | AREA KM$^2$ | AREA_UNITS | NO_POINTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 6.4422 | 21.4741 | 1 | 0.4510 | -0.0869 | 0.5379 |
| 1 | Clay | 43.0479 | 143.4931 | 4 | -0.0816 | 0.4153 | -0.4969 |
| 15 | Sandy Loam | 0.2231 | 0.7436 | 0 | | | |

Table 5-9. Attributes of Output Weights of Land Capability Evidential Theme (Cipero)

| CLASS | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|
| 0 | 6.4422 | 21.4741 | 1 | 0.4510 | -0.0869 | 0.5379 |
| 3 | 8.8970 | 29.6568 | 0 | | | |
| 4 | 10.5541 | 35.1804 | 1 | -0.0615 | 0.0160 | -0.0775 |
| 5 | 16.3290 | 54.4301 | 1 | -0.5082 | 0.1810 | -0.6892 |
| 6 | 7.4908 | 24.9693 | 2 | 1.0292 | -0.3566 | **1.3858** |

| CLASS | CAPDESCP |
|---|---|
| 0 | |
| 3 | good land, requires moderate to intensive conservation and management practices |
| 4 | moderately good land, requires intensive conservation and management practices |
| 5 | fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope |
| 6 | unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest |

Table 5-10. Attributes of Output Weights of Relief Evidential Theme (Cipero)

| CLASS | RELIEF | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | | 6.6653 | 22.2177 | 1 | 0.4153 | -0.0816 | 0.4969 |
| 1 | Flat | 8.8970 | 29.6568 | 0 | | | |
| 6 | Hilly | 24.7863 | 82.6211 | 2 | -0.2264 | 0.1856 | -0.4121 |
| 17 | Rolling | 9.3645 | 31.2151 | 2 | 0.7886 | -0.3102 | **1.0988** |

## Pilote Watershed

Table 5-11. Attributes of Output Weights of Landform Evidential Theme (Pilote)

| CLASS | LFORMDESCP | AREA KM$^2$ | AREA_UNITS | NO_POINTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 0.0893 | 0.2233 | 0 | | | |
| 1 | Alluvial Plains and Valleys | 50.0596 | 125.1489 | 7 | 1.1361 | -1.2168 | **2.3528** |
| 2 | Terraces | 0.7059 | 1.7647 | 0 | | | |
| 3 | Uplands | 141.9898 | 354.9745 | 2 | -1.2111 | 1.1194 | -2.3305 |

Table 5-12. Attributes of Output Weights of Soil Texture Evidential Theme (Pilote)

| CLASS | TEXTURE | AREA KM$^2$ | AREA_UNITS | NO_POINTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 0.0893 | 0.2233 | 0 | | | |
| 1 | Clay | 72.9923 | 182.4808 | 0 | | | |
| 3 | Fine Sandy Clay | 48.8533 | 122.1333 | 1 | -0.8348 | 0.1780 | -1.0128 |
| 5 | Fine Sandy Loam | 7.6775 | 19.1938 | 0 | | | |
| 7 | Loamy Fine Sand | 43.7603 | 109.4007 | 1 | -0.7237 | 0.1424 | -0.8662 |
| 8 | Loamy Sand | 8.7801 | 21.9502 | 2 | 1.6620 | -0.2082 | **1.8702** |
| 10 | Peaty Clay | 1.4208 | 3.5519 | 0 | | | |
| 12 | Sand | 8.5711 | 21.4277 | 5 | 2.7726 | -0.7756 | **3.5482** |
| 14 | Sandy Clay Loam | 0.6820 | 1.7050 | 0 | | | |
| 15 | Sandy Loam | 0.0179 | 0.0447 | 0 | | | |

Table 5-13. Attributes of Output Weights of Land Capability Evidential Theme (Pilote)

| CLASS | AREA KM$^2$ | AREA_UNITS | NO_POINTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|
| 0 | 0.0893 | 0.2233 | 0 | | | |
| 1 | 0.8120 | 2.0301 | 0 | | | |
| 3 | 24.2981 | 60.7453 | 0 | | | |
| 4 | 34.4862 | 86.2154 | 7 | 1.5358 | -1.3208 | **2.8567** |
| 5 | 40.8227 | 102.0569 | 2 | 0.0495 | -0.0137 | 0.0632 |
| 6 | 63.5369 | 158.8422 | 0 | | | |
| 7 | 28.7993 | 71.9982 | 0 | | | |

| CLASS | CAPDESCP |
|---|---|
| 0 | Not Given |
| 1 | very good land, easily cultivated |
| 3 | good land, requires moderate to intensive conservation and management practices |
| 4 | moderately good land, requires intensive conservation and management practices |
| 5 | fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope |
| 6 | unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest |
| 7 | unsuitable for agriculture due to very steep slopes, should be left under indigenous growth or forest |

Table 5-14. Attributes of Output Weights of Relief Evidential Theme (Pilote)

| CLASS | RELIEF | AREA KM$^2$ | AREA_UNITS | NO_POINTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 49.7004 | 124.2510 | 1 | -0.8521 | 0.1840 | -1.0361 |
| 1 | Flat | 49.3775 | 123.4438 | 7 | 1.1506 | -1.2216 | **2.3722** |
| 6 | Hilly | 10.8682 | 27.1706 | 0 | | | |
| 10 | Low hills | 2.5873 | 6.4682 | 0 | | | |
| 12 | Low undulating hills | 1.4501 | 3.6252 | 0 | | | |
| 14 | Mildly undulating | 0.6880 | 1.7200 | 0 | | | |
| 17 | Rolling | 67.7914 | 169.4784 | 1 | -1.1647 | 0.3224 | -1.4871 |
| 22 | Steep | 2.5920 | 6.4801 | 0 | | | |
| 23 | Undulating | 7.7896 | 19.4740 | 0 | | | |

## South Oropouche Watershed

Table 5-15. Attributes of Output Weights of Landform Evidential Theme (South Oropouche)

| CLASS | LFORMDESCP | AREA $KM^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 0.0463 | 0.0289 | 0 | | | |
| 1 | Alluvial Plains and Valleys | 134.6719 | 84.1700 | 1 | -0.7799 | 0.2192 | -0.9991 |
| 2 | Terraces | 7.8339 | 4.8962 | 0 | | | |
| 3 | Uplands | 295.7162 | 184.8226 | 6 | 0.2464 | -0.8374 | **1.0838** |

Table 5-16. Attributes of Output Weights of Soil Texture Evidential Theme (South Oropouche)

| CLASS | TEXTURE | AREA $KM^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 1 | Clay | 22.8780 | 14.2988 | 1 | | | |
| 3 | Fine Sandy Clay | 0.4329 | 0.2705 | 0 | | | |
| 14 | Sandy Clay Loam | 0.1257 | 0.0786 | 0 | | | |

Table 5-17. Attributes of Output Weights of Land Capability Evidential Theme (South Oropouche)

| CLASS | AREA $KM^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|
| 0 | 0.0463 | 0.0289 | 0 | | | |
| 3 | 78.2682 | 48.9176 | 1 | -0.2285 | 0.0437 | -0.2722 |
| 4 | 154.5175 | 96.5734 | 2 | -0.2152 | 0.1010 | -0.3162 |
| 5 | 122.2863 | 76.4289 | 2 | 0.0243 | -0.0096 | 0.0339 |
| 6 | 73.9659 | 46.2287 | 2 | 0.5448 | -0.1553 | **0.7001** |
| 7 | 9.1842 | 5.7401 | 0 | | | |

| CLASS | CAPDESCP |
|---|---|
| 0 | |
| 3 | good land, requires moderate to intensive conservation and management practices |
| 4 | moderately good land, requires intensive conservation and management practices |
| 5 | fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope |
| 6 | unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest |
| 7 | unsuitable for agriculture due to very steep slopes, should be left under indigenous growth or forest |

Table 5-18. Attributes of Output Weights of Relief Evidential Theme (South Oropouche)

| CLASS | RELIEF | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 51.3436 | 32.0898 | 2 | 0.9300 | -0.2169 | 1.1469 |
| 1 | Flat | 134.6719 | 84.1700 | 1 | -0.7799 | 0.2192 | -0.9991 |
| 5 | Gently rolling | 0.0094 | 0.0059 | 0 | | | |
| 6 | Hilly | 125.1215 | 78.2009 | 1 | -0.7054 | 0.1873 | -0.8926 |
| 9 | Low hill | 1.6351 | 1.0219 | 0 | | | |
| 10 | Low hills | 6.1132 | 3.8208 | 0 | | | |
| 11 | Low rolling hills | 7.2920 | 4.5575 | 0 | | | |
| 14 | Mildly undulating | 0.3812 | 0.2382 | 0 | | | |
| 17 | Rolling | 93.6106 | 58.5066 | 3 | 0.7231 | -0.3265 | **1.0496** |
| 23 | Undulating | 10.1156 | 6.3223 | 0 | | | |
| 24 | Undulating hills | 7.9742 | 4.9839 | 0 | | | |

## Rest North Watershed

Table 5-19. Attributes of Output Weights of Landform Evidential Theme (Rest North)

| CLASS | LFORMDESCP | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 1 | Alluvial Plains and Valleys | 3.1795 | 15.8973 | 1 | 1.0795 | -0.0793 | **1.1588** |
| 3 | Uplands | 77.5430 | 387.7152 | 8 | -0.0793 | 1.0795 | -1.1588 |

Table 5-20. Attributes of Output Weights of Soil Texture Evidential Theme (Rest North)

| CLASS | TEXTURE | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 1 | Clay | 61.9658 | 309.8291 | 3 | -0.8470 | 1.0976 | -1.9446 |
| 2 | Clay loam | 0.4556 | 2.2778 | 1 | 3.5355 | -0.1145 | **3.6501** |
| 3 | Fine Sandy Clay | 15.5314 | 77.6570 | 5 | 1.1044 | -0.6074 | **1.7118** |
| 5 | Fine Sandy Loam | 0.0829 | 0.4147 | 0 | | | |
| 7 | Loamy Fine Sand | 2.1789 | 10.8947 | 0 | | | |
| 8 | Loamy Sand | 0.0346 | 0.1728 | 0 | | | |
| 10 | Peaty Clay | 0.1994 | 0.9971 | 0 | | | |
| 14 | Sandy Clay Loam | 0.2739 | 1.3693 | 0 | | | |

Table 5-21. Attributes of Output Weights of Land Capability Evidential Theme (Rest North)

| CLASS | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|
| 3 | 2.2341 | 11.1703 | 0 | | | |
| 4 | 9.2191 | 46.0955 | 0 | | | |
| 5 | 25.6302 | 128.1511 | 6 | 0.7672 | -0.7282 | **1.4954** |
| 6 | 22.3394 | 111.6970 | 0 | | | |
| 7 | 21.2997 | 106.4986 | 3 | 0.2397 | -0.1013 | 0.3410 |

| CLASS | CAPDESCP |
|---|---|
| 3 | good land, requires moderate to intensive conservation and management practices |
| 4 | moderately good land, requires intensive conservation and management practices |
| 5 | fairly good land, should be used for forest, tree crops, grazing and buildings depending on the slope |
| 6 | unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth or forest |
| 7 | unsuitable for agriculture due to very steep slopes, should be left under indigenous growth or forest |

Table 5-22. Attributes of Output Weights of Relief Evidential Theme (Rest North)

| CLASS | RELIEF | AREA KM$^2$ | AREA_UNITS | NO_PTS | W+ | W- | CONTRAST |
|---|---|---|---|---|---|---|---|
| 0 | Not Given | 17.0415 | 85.2073 | 5 | 1.0055 | -0.5837 | 1.5892 |
| 1 | Flat | 3.1795 | 15.8973 | 1 | 1.0795 | -0.0793 | **1.1588** |
| | Hilly | 14.9182 | 74.5912 | 0 | | | |
| 10 | Low hills | 9.3304 | 46.6521 | 0 | | | |
| 12 | Low undulating hills | 0.8798 | 4.3988 | 0 | | | |
| 17 | Rolling | 23.2740 | 116.3698 | 3 | 0.1486 | -0.0668 | 0.2154 |
| 23 | Undulating | 12.0992 | 60.4960 | 0 | | | |

## Tables 5-23 – 5-38 (Data Outputs Generated by Weights of Evidence Analysis)

### Cipero Watershed

Table 5-23. Attributes of Weights of Evidence (Cipero)

| EVIDENCE_T | CLASS_FIEL | W_99 | W1 | W2 |
|---|---|---|---|---|
| Cipercapa_shp | Capabil_2 | 0.0000 | -0.3545 | 1.0168 |
| Perrelief_shp | Relief_2 | 0.0000 | -0.3149 | 0.8103 |
| Iperlandf_shp | Landform2 | 0.0000 | -0.4430 | 0.1501 |
| Sites.shp | | 5.0000 | 170.0000 | 0.0294 |

Table 5-24. Attributes of Response Theme (Cipero)

| VALUE | COUNT | PERRELIEF_ | IPERLANDF_ | CIPERCAPA_ | AREA $M^2$ | TRNGPOINTS |
|---|---|---|---|---|---|---|
| 1 | 2690415 | -99 | -99 | -99 | 2690415.00 | 0 |
| 2 | 14880402 | 1 | 1 | 1 | 14880402.00 | 1 |
| 3 | 17129069 | 1 | 2 | 1 | 17129069.00 | 0 |
| 4 | 8926771 | 2 | 2 | 1 | 8926771.00 | 2 |
| 5 | 7373343 | 1 | 2 | 2 | 7373343.00 | 2 |

Table 5-25. Attributes of Posterior Probability (Cipero)

| VALUE | COUNT | PERRELIEF_ | IPERLANDF_ | CIPERCAPA_ | AREA M² | TRNGPOINTS | LRPOSTPROB | SITE FAVORABILITY |
|---|---|---|---|---|---|---|---|---|
| 1 | 2690415 | -99 | -99 | -99 | 2690415.00 | 0 | **0.00015000** | **Reclassified as 1** |
| 2 | 14880402 | 1 | 1 | 1 | 14880402.00 | 1 | **0.01976000** | **Reclassified as 1** |
| 3 | 17129069 | 1 | 2 | 1 | 17129069.00 | 0 | **0.00000000** | **Reclassified as 1** |
| 4 | 8926771 | 2 | 2 | 1 | 8926771.00 | 2 | **0.06298000** | **Reclassified as 2** |
| 5 | 7373343 | 1 | 2 | 2 | 7373343.00 | 2 | **0.07525000** | **Reclassified as 3** |

Table 5-26. Attributes of Conditional Independence (Cipero)

| ETHEME | PERLANDF_S | IPERCAPA_S |
|---|---|---|
| Errelief_shp | 0.3613 | 0.5762 |
| Perlandf_shp | | 0.3613 |
| Values < .05 indicate some conditional dependence | | |

## Pilote Watershed

(The Weights of Evidence, Response Theme and Posterior Probability Results of the Pilote Watershed were rejected because of poor Conditional Independence Results (Table 5-30)

Table 5-27. Attributes of Weights of Evidence (Pilote)

| EVIDENCE_T | CLASS_FIEL | W_99 | W1 | W2 |
|---|---|---|---|---|
| Pilottext_shp | Texture_2 | 0.0000 | -1.3059 | 2.2734 |
| Pilocapa_shp | Capabil_2 | 0.0000 | -1.2036 | 1.5021 |
| Ilotrelie_shp | Relief_2 | 0.0000 | -1.1002 | 1.1035 |
| Pilolandf_shp | Landform2 | 0.0000 | -1.0953 | 1.0887 |
| Sites.shp | | 9.0000 | 490.0000 | 0.0184 |

Table 5-28. Attributes of Response Theme (Pilote)

| VALUE | COUNT | PILOTTEXT_ | PILOLANDF_ | ILOTRELIE_ | PILOCAPA_S | AREA M$^2$ | TRNGPOINTS |
|---|---|---|---|---|---|---|---|
| 1 | 8612620 | -99 | -99 | -99 | -99 | 8612620.00 | 0 |
| 2 | 121947458 | 1 | 1 | 1 | 1 | 121947458.00 | 2 |
| 3 | 31599187 | 1 | 2 | 2 | 1 | 31599187.00 | 0 |
| 4 | 16622668 | 2 | 2 | 2 | 2 | 16622668.00 | 6 |
| 5 | 16536102 | 1 | 1 | 1 | 2 | 16536102.00 | 0 |
| 6 | 681965 | 1 | 2 | 1 | 1 | 681965.00 | 0 |

Table 5-29. Attributes of Posterior Probability (Pilote)

| VALUE | COUNT | PILOTTEXT | PILOLANDF | ILOTRELIE | PILOCAPA_S | AREA $M^2$ | TRNGPTS | LRPOSTPROB |
|---|---|---|---|---|---|---|---|---|
| 1 | 8612620 | -99 | -99 | -99 | -99 | 8612620.00 | 0 | 0.00001000 |
| 2 | 121947458 | 1 | 1 | 1 | 1 | 121947458.00 | 2 | 0.00652000 |
| 3 | 31599187 | 1 | 2 | 2 | 1 | 31599187.00 | 0 | 0.00000000 |
| 4 | 16622668 | 2 | 2 | 2 | 2 | 16622668.00 | 6 | 0.12617000 |
| 5 | 16536102 | 1 | 1 | 1 | 2 | 16536102.00 | 0 | 0.00000000 |
| 6 | 681965 | 1 | 2 | 1 | 1 | 681965.00 | 0 | 0.00000000 |

Table 5-30. Attributes of Conditional Independence (Pilote)

| ETHEME | ILOLANDF_S | LOTRELIE_S | PILOCAPA_S |
|---|---|---|---|
| Ilottext_shp | 0.0000 | 0.0000 | 0.0000 |
| Ilolandf_shp | | 0.0000 | 0.0000 |
| Lotrelie_shp | | | 0.0000 |
| Values < .05 indicate some conditional dependence | | | |

## South Oropouche

Table 5-31. Attributes of Weights of Evidence (South Oropouche)

| EVIDENCE_T | CLASS_FIEL | W_99 | W1 | W2 |
|---|---|---|---|---|
| Ororelief_shp | Relief_2 | 0.0000 | -0.3276 | 0.7274 |
| Sorocapa_shp | Capabil_2 | 0.0000 | -0.1576 | 0.5564 |
| Sorolandf_shp | Landform2 | 0.0000 | -0.8475 | 0.2514 |
| Sites.shp | | 7.0000 | 273.9100 | 0.0256 |

Table 5-32. Attributes of Response Theme (South Oropouche)

| VALUE | COUNT | SOROCAPA_S | ORORELIEF_ | SOROLANDF_ | AREA $M^2$ | TRNGPOINTS |
|---|---|---|---|---|---|---|
| 1 | 5615182 | -99 | -99 | -99 | 5615182.00 | 0 |
| 2 | 40268557 | 2 | 1 | 2 | 40268557.00 | 0 |
| 3 | 69189146 | 1 | 2 | 2 | 69189146.00 | 1 |
| 4 | 158203632 | 1 | 1 | 2 | 158203632.00 | 3 |
| 5 | 133016551 | 1 | 1 | 1 | 133016551.00 | 1 |
| 6 | 9083254 | 2 | 1 | 1 | 9083254.00 | 0 |
| 7 | 22873678 | 2 | 2 | 2 | 22873678.00 | 2 |

Table 5-33. Attributes of Posterior Probability (South Oropouche)

| VALUE | COUNT | SOROCAPA_S | ORORELIEF | SOROLANDF | AREA $M^2$ | TRNGPOINTS | LRPOSTPROB | SITE FAVORABILITY |
|---|---|---|---|---|---|---|---|---|
| 1 | 5615182 | -99 | -99 | -99 | 5615182.00 | 0 | 0.02106000 | **Reclassified as 1** |
| 2 | 40268557 | 2 | 1 | 2 | 40268557.00 | 0 | 0.03259000 | **Reclassified as 2** |
| 3 | 69189146 | 1 | 2 | 2 | 69189146.00 | 1 | 0.04316000 | **Reclassified as 2** |
| 4 | 158203632 | 1 | 1 | 2 | 158203632.00 | 3 | 0.02106000 | **Reclassified as 1** |
| 5 | 133016551 | 1 | 1 | 1 | 133016551.00 | 1 | 0.01049000 | **Reclassified as 1** |
| 6 | 9083254 | 2 | 1 | 1 | 9083254.00 | 0 | 0.01633000 | **Reclassified as 1** |
| 7 | 22873678 | 2 | 2 | 2 | 22873678.00 | 2 | 0.06595000 | **Reclassified as 3** |

Table 5-34. Attributes of Conditional Independence (South Oropouche)

| ETHEME | RORELIEF_S | OROLANDF_S |
|---|---|---|
| Sorocapa_shp | 0.2771 | 0.4945 |
| Rorelief_shp<br>Values < .05 indicate some conditional dependence | | 0.3496 |

**Rest North Watershed**

Table 5-35. Attributes of Weights of Evidence (Rest North)

| EVIDENCE_T | CLASS_FIEL | W_99 | W1 | W2 |
|---|---|---|---|---|
| Tnortcapa_shp | Capabil_2 | 0.0000 | -5.8465 | 1.1758 |
| Tnortext2_shp | Texture_3 | 0.0000 | -0.3057 | 0.7686 |
| Stnortext_shp | Texture_2 | 0.0000 | 0.0031 | -0.9330 |
| Nortrelie_shp | Relief_2 | 0.0000 | 0.0357 | -2.9183 |
| Tnorlandf_shp | Landform2 | 0.0000 | 0.0357 | -2.9183 |
| Sites.shp | | 9.0000 | 402.5000 | 0.0224 |

Table 5-36. Attributes of Response Theme (Rest North)

| VALUE | COUNT | PILOTTEXT_ | PILOLANDF_ | ILOTRELIE_ | PILOCAPA_S | AREA M² | TRNGPOINTS |
|---|---|---|---|---|---|---|---|
| 1 | 8612620 | -99 | -99 | -99 | -99 | 8612620.00 | 0 |
| 2 | 121947458 | 1 | 1 | 1 | 1 | 121947458.00 | 2 |
| 3 | 31599187 | 1 | 2 | 2 | 1 | 31599187.00 | 0 |
| 4 | 16622668 | 2 | 2 | 2 | 2 | 16622668.00 | 6 |
| 5 | 16536102 | 1 | 1 | 1 | 2 | 16536102.00 | 0 |
| 6 | 681965 | 1 | 2 | 1 | 1 | 681965.00 | 0 |

Table 5-37. Attributes of Posterior Probability (Rest North)

| VALUE | COUNT | TNORTEXT2 | NORTRELIE | TNORLANDF | TNORTCAPA | STNORTEXT | AREA $M^2$ | TRNG PTS | LRPOSTPROB | SITE FAVORABILITY |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5696024 | -99 | -99 | -99 | -99 | -99 | 5696024.00 | 0 | 0.00004000 | Reclassified as 1 |
| 2 | 37986145 | 1 | 1 | 1 | 1 | 1 | 37986145.00 | 0 | 0.00000000 | Reclassified as 1 |
| 3 | 19994895 | 1 | 1 | 1 | 2 | 1 | 19994895.00 | 3 | 0.02913000 | Reclassified as 2 |
| 4 | 10798247 | 2 | 1 | 1 | 1 | 1 | 10798247.00 | 0 | 0.00001000 | Reclassified as 1 |
| 5 | 2277877 | 1 | 2 | 2 | 1 | 1 | 2277877.00 | 0 | 0.00000000 | Reclassified as 1 |
| 6 | 16103 | 1 | 2 | 2 | 1 | 2 | 16103.00 | 0 | 0.00000000 | Reclassified as 1 |
| 7 | 3290408 | 2 | 1 | 1 | 2 | 1 | 3290408.00 | 2 | 0.10839000 | Reclassified as 3 |
| 8 | 79178 | 1 | 2 | 2 | 2 | 1 | 79178.00 | 0 | 0.00016000 | Reclassified as 1 |
| 9 | 361123 | 1 | 2 | 2 | 2 | 2 | 361123.00 | 0 | 0.00000000 | Reclassified as 1 |

Table 5-38. Attributes of Conditional Independence (Rest North)

| ETHEME | ORTRELIE_S | NORLANDF_S | NORTCAPA_S | TNORTEXT_S |
|---|---|---|---|---|
| Nortext2_shp | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| Ortrelie_shp | | 1.0000 | 1.0000 | 1.0000 |
| Norlandf_shp | | | 1.0000 | 1.0000 |
| Nortcapa_shp | | | | 1.0000 |
| Values < .05 indicate some conditional dependence. | | | | |

# CHAPTER 6
# RESULTS AND DISCUSSION

## Weights of Evidence Results and Analysis

Predictive models for Cipero, South Oropouche and Rest North were generated by summing the weights of evidence of the binary maps related to these watersheds. The various overlap combinations of the binary maps resulted in the highest cumulative weights in the areas where archaeological sites are likely to be found.

The sum of weights for Cipero W2 (Table 5-23) clearly indicates that Land Capability (unsuitable for agriculture due to slope and/or water limitations has the highest weighted value [1.0168], followed by Relief (Rolling) [0.8103] and Landform (Uplands) [0.1501]. Cipero's "high favorability" areas constitute 14%, "moderate favorability" **18%** and "low favorability" areas comprise the remaining 68% of the watershed (Table 6-1 and Figures 6-1 and 6-4).

With respect to South Oropouche (Table 5-31), Relief (Rolling) has the highest weighted value [0.7274], followed by Land Capability (land unsuitable for agriculture due to slope and/or water limitations, should be left under indigenous growth) [0.5564] and Landform (Uplands) [0.2514]. South Oropouche's "high" favorability areas constitute 5%, its "moderate" favorability areas 25% while its "low" favorability areas make up the remaining 70% of the watershed (Table 6-2 and Figures 6-2 and 6-5). A markedly different situation exists in regards to Rest North (Table 5-35), which has Land Capability (fairly good land) predominating with a weighted value of

[1.1758], followed by Soil Texture (fine sandy clay) [0.7686]. Negatives values for Soil Texture (clay loam) [-0.9330], Relief (Flat) [-2.9183) and Landform (Alluvial Plains and Valleys) [-2.9183) render them as totally insignificant as predictive themes. Rest North's "high" favorability areas comprise 4%, its "moderate" favorability 25% and its "low" favorability areas comprise the remaining 71% of the region of interest (Table 6-3; Figures 6-3 and 6-6). The conditional independence of Rest North (Table 5-38) is a perfect 1. Although this level of conditional independence does not occur in practice (see Boleneus et al. 2002), it suggests that the weights of evidence results for this watershed are very reliable.

It could therefore be argued that Land Capability (whether unsuitable land for agriculture or fairly good land) has a significant bearing on site location in all three watersheds, followed by Relief (Rolling). Landform (Uplands) is absent in Rest North but is present in "modest" quantities in South Oropouche and Cipero. Soil Texture (fine sandy clay), which has been described as a "free internal drainage soil", only figures prominently in the Rest North watershed.

As discussed in Chapter 5, the original refined descriptive model for this study reads as follows:

<u>Pre-Columbian sites in Trinidad are likely to be found in areas with hilly relief in alluvial plains and valleys, in areas with very good to moderately good land capability and free internal drainage soils.</u>

When compared with the above model, the weights of evidence analysis of the three watersheds, like the above descriptive model, places significant weighting on "hilly" relief. But the weights of evidence model places no weighting on "Alluvial Plains

and Valleys" and on Land Capability (very good to moderately good land). There is, however, some importance ascribed to "free internal drainage soils" in relation to the Rest North watershed. Landform (Uplands) has some leverage in site location as reflected in South Oropouche and Cipero. Given that the weights of evidence analysis was applied to only a small number of watersheds in south and southwestern Trinidad, the following (weights of evidence) revised descriptive model is hereby presented:

Based on weights of evidence analysis of the Cipero, South Oropouche and Rest North watersheds in southern and southwestern Trinidad, pre-Columbian archaeological sites in this part of the island are likely to be found in areas with (a) hilly relief (b) land capability characterized by either fairly good land or land unsuitable for agriculture due to slope and/or water limitations (c) upland landforms and (d) "free internal drainage soils" along the south coast of the island.

Some archaeologists clearly seem to believe that the data they study are somehow directly and automatically linked with the past, and perhaps in no other area of archaeological "specialty" is this as pronounced as in predictive modeling. Little real introspection is required to arrive at the realization that the variables and correlations, which comprise the entire substance of "inductive" predictive modeling experiments, are solely contemporary (Ebert 2000:130). In essence, predictive modeling cannot be a productive archaeological pursuit without the explicit realization that statistical tests and correlations can only inform us about coincidences in the present, which must then be linked with the past through the process of explanation (Ebert 2000:130).

There are, for example, significant challenges associated with interpreting archaeological site prediction on the basis of Land Capability classifications. This taxonomic system is based on contemporary (Hardy 1974:55; 1981:39) not prehistoric conditions and as such retrodicting these classifications to pre-Columbian landscapes is fraught with problems. For one thing, it seems simply incongruous associating

predominantly pre-Columbian horticultural settlements[1] with "unsuitable land for agriculture." However, the fact is that prehistoric inhabitants often chose to live in places totally unsuitable for agriculture. Not only would this have afforded villagers additional arable land but it would also have ensured that the hustle and bustle and village life did not interfere with nearby agricultural fields. Further compounding the issue is that what is now being described as "unsuitable land for agriculture due to slope and/water limitations" might have been the reverse deep in time. It is possible for climatic changes to have adversely and dramatically affected vegetation, the availability of underground water and the organic composition of soils overtime. For example, around AD 500 there were hyper arid conditions due to major climatic changes in the southern Caribbean (Hodell et al. 1991; Meggers 1996). Moreover, deforestation and frequent indiscriminate land use during the post-Columbian era would conceivably have taken a heavy toll on the physical integrity of landscapes (Deagan 1990). However, despite their creation for contemporary use, Land Capability classifications are still important for weights of evidence analysis, as the location of sites cannot be divorced their current geographical context (Barker 1989). Even though correlation does not necessary suggest causation (Arjoon 1999), establishing clear associations between sites in Trinidad and Land Capability classes can shed light on where sites are likely to be found.

The weighted value of "hilly" Relief in both South Oropouche and Cipero accords well with general settlement predispositions among pre-Columbian peoples on some islands of the Caribbean. These settlement sites appeared to have allowed a commanding view of the surrounding areas, suggesting that considerations of observation and defense

[1] It is important to note that 3 out of the 8 sites used for weights of evidence modeling in South Oropouche are Archaic (forager) sites (Table 5-5).

influenced this type of settlement location (Boomert 2000:264). Dubbed "hill top" settlements (Howard 1965), a significant number of Jamaica's pre-Columbian habitation sites are concentrated on the island's foothills. In his study of Kingston, Jamaica, Allsworth-Jones (1999) cited several pre-Columbian hilltop settlements within that general area such as Harbour View, Bellevue, Chancery Hall, Rodney's House and Norbrook. However, there is also an almost equally numerous number of coastal sites in Jamaica for example Little River, Mammee Bay and Port Henderson (Aarons 1984; De Wolf 1952). It is also important to note that coastal, low-lying sites abound in the Bahamas (Keegan 1992) and Barbados (Drewett 1991). While acknowledging that several Saladoid settlement sites in Trinidad are located inland on ridges or hilltops, Boomert (2000:264) argues that these sites are in the minority as there are several coastal Saladoid and Guayabitoid habitation sites on the island. It seems therefore that the "hilly" Relief is more specific to South Oropouche and Cipero as a predictive variable and should not necessarily be construed as reflective of general trends in pre-Columbian Trinidad and the Caribbean. A similar scenario exists in relation to the weighted value of Landform (Uplands) in both South Oropouche and Cipero. While it is true that Landform (Alluvial Plains and Valleys) may be a more germane descriptive model for archaeological site prediction in some of the larger islands of the Caribbean (see Allsworth-Jones 1999; Curet 1992; Keegan 2000; Rodríguez 1992), weights of evidence analysis has clearly demonstrated that Landform (Uplands) is more usefully applied as a predictive theme specifically to these regions of interest in southwestern Trinidad.

The relatively strong weighted value and concurrence of "fairly good land for agriculture" Land Capability with "fine sandy clay" Soil Texture in Rest North (Table 6-

3) suggest that the "high" favorability areas in this watershed had much potential for pre-Columbian horticultural activity. As mentioned earlier, fine sandy clay is a "free internal drainage soil" and therefore highly suitable for a variety of cultigens grown and consumed by the Saladoid, Barrancoid and the Guayabitoid peoples. Keegan (2000) and (Petersen 1997) assert that the Saladoid peoples practiced a mixed economy of which root crop agriculture figured prominently. The presence of clay griddles is used to infer that bitter manioc was cultivated for cassava bread (Veloz Maggiolo 1997). Sweet potatoes also were grown at contact, but there is no archaeological evidence for root crops before the contact period [e.g., En Bas Saline, Haiti (Newson 1993). Such foods tend to thrive well in well-drained soils such as "fine sandy clay." Throughout the Caribbean, horticultural pre-Columbian populations for example the Tainos in Manuabo, Puerto Rico (Curet 1992) were apparently attracted to areas containing "free internal drainage soils" conducive to root crop agriculture. Anna Roosevelt (1997:168-169) provides evidence, which suggests that the Arauquinoid peoples of the mainland and by extension, the Guayabitoid peoples of Trinidad had chiefdom societies. According to Roosevelt (1997) the anthropomorphic imagery of the Arauquinoid peoples was associated with some form of a chiefly cult, glorifying the memorial images of the ancestors of an elite people. The Arauquinoid period (AD 900 – 1300) was essentially characterized by incipient maize cultivation and the emergence of ranked societies in the Middle Orinoco (Roosevelt 1997:168-169). Clearly then, both Saladoid/Barrancoid and Guayabitoid peoples were both engaged in horticultural activities that required "free internal drainage soils," although the Guayabitoid, being the more socially complex group, would have produced cultivars on a much more sophisticated scale. The presence

of "fairly good land" Land Classification in addition to "free internal drainage soils" might therefore have factored in the decision of pre-Columbian groups to settle within the Rest North watershed.

This should be viewed against the reality that soils have played an integral role in archaeology. Indeed, soils have been long recognized as important in the interpretation of archaeological sites and regions (Holliday 1992:101). The broadest systematic application of soils in archaeological research is probably in the area of soil chemistry as an indicator of habitations, habitation patterns, and agricultural activity (e.g. Eidt 1977, 1985; Hassan 1981; Sjoberg 1976; Solecki 1951). In Amazonian archaeology, for example, the *terra preta do Indio* or "black Indian soils" found throughout the Amazonian Basin (Edit 1984; Falesi 1974; Smith 1980) are strongly correlated with high agricultural activity.

However, the scoring of an area by the model as having a very high "attractiveness" for the use of habitation sites (as is the case with Rest North) does not mean that the probability of discovering a site in that area is 100%. Sites are relatively rare concentrations of recoverable remains within an active landscape. Although the model may assign a high probability score to an area, it does not necessarily follow that a sufficient amount of human activity occurred at the location to have produced nonperishable and preserved remains (Duncan and Beckman 2000).

Perhaps, one of the major weaknesses of weights of evidence models, as with most GIS predictive models, is that it provides an etic rather than an emic perspective on settlement location studies. Anthropologist Marvin Harris has defined etic categories as a research strategy based on concepts and distinctions that are meaningful and appropriate

to the scientific community (Harris 1968). Hence, weights of evidence furnishes the relative predictive "strength" of various themes on the basis of statistics generated by a computer algorithm. However, this approach does not capture the emic perspective, which is meaningful, significant and "appropriate" to the participants of a given culture (Thomas 1999).

To illustrate: Ebert (2000:131) argues that site-centered predictive modeling ignores a vast body of anthropological and archaeological evidence and thought that emphasizes that people, the things they do, and all other aspects of human behavior are a systemically organized whole. "Sites," in fact, are not independent entities at all, but components of systems – and their locations are dependent upon the locations of other components of that system, including other sites. Where the site is located and what is done there may therefore be quite independent of what resources are located nearby. What is located where sites are not is therefore probably just as important a factor in site placement as what is found where they are (Ebert 2000:131). Equally important, weights of evidence does not take into consideration the symbolic and religious reasons, which might underlie the selection of particular sites over and above others (Knapp and Ashmore 1999). But we should not be apologetic about the cultural materialistic approaches of weights of evidence, as similar to the vast majority of GIS predictive models, it operates largely within an etic environmental deterministic framework (Gaffney 1995).

Not unexpectedly, applying weights of evidence analysis in this dissertation was not without some technical problems. Firstly, there was some level of uncertainty about the precise location of some of the sites used in the model. However, this uncertainty was

restricted to two sites in South Oropouche (Siparia and Banwari Trace) (Table 5-4) whose coordinates were recorded autonomously with a global positioning systems (GPS) receiver. In the near future, their coordinates will be rechecked and given post processed GPS coordinates. In addition, some of the data related to the prediction themes were missing, as unfortunately not every feature within the selected environmental themes was mapped by the Land Survey Department of the University of the West Indies. The weights of evidence extension, however, expected such eventualities and made allowances for them by including -99 in its analysis parameters (which is the default integer for missing data).

Despite this, an archaeological predictive model is always a work in progress. There is no absolute correlation between predictions and site locations, merely a tool of confidence in which reasonably reliable results are produced (Duncan and Beckman 2000). Despite the technical challenges, the application of GIS weights of evidence has produced three useful archaeological predictive models of Cipero, South Oropouche and Rest North. In no other endeavor will the value of these models be more relevant than in the cultural resource management of pre-Columbian archaeological sites in Trinidad.

**The Weights of Evidence Predictive Models and CRM in Trinidad**

In Chapter 1, it was established that Trinidad has institutional support for archaeological heritage management. A case will now be made for the judicious use of the GIS weights of evidence predictive models in effectively managing the island's pre-Columbian sites. Firstly, it is important to point out that a cultural resource cannot be managed until it is found (Drewett 1999). Conventional methods require field archaeologists to locate the resource. Given the fact that like many countries of the

neotropics (Zeidler 1995), Trinidad's archaeology suffers from low site accessibility and poor ground visibility, site location efforts are frequently fraught with difficulties. For example, approximately 80% of the Rest North watershed is comprised of thick forest cover. On the other hand, a mix of sugar cane, rice and vegetable farming as well as fairly large towns and villages characterizes South Oropouche and Cipero.

Pre-Columbian sites, because they are invariably represented by pottery and stone artifacts, may be inconspicuous on the landscape. Traveling back and forth in search of sites through often difficult terrain can be both costly and time-consuming. By providing predictive models of where the most favorable site location areas are situated, researchers will be spared significant monetary costs and time wastage invariably associated with ground surveys over large areas. The initial costs of the GIS data sets required for predictive modeling are high (Bernardsen 1999). However, investing in GIS data and expertise is a sound investment as once the models are created, the data sets as well as the models themselves may be used and re-used for several years. Like other academic, professional or scientific fields, CRM benefits from new ideas and improvements in method and technique. Many CRM activities are part of the "cost of business" for governments and private institutions, so improvements in efficiency and reductions in cost through GIS applications are especially important (MacManamon and Hatton 2000).

This is not to infer that these GIS predictive models will make ground surveys in Trinidad redundant. While extolling the virtues of predictive models, Zeidler (1995:19) argues that these models often need to be "ground-truthed" or georegistered with Global Positioning System (GPS) technology, a practice which has been shown to be reasonably effective even in tropical rain forest environments (Baksh 1991; Chagnon 1991; Wilke

1989). Precise location al information on each archaeological site can be acquired as the field survey proceeds, and all the relevant archaeological and ecological variables can be incorporated into a GIS format for statistical analysis and long-term data management (Zeidler 1995:19). In discussing the CRM policy of English Heritage, Orton's (2000) cites a mitigation strategy as a major tenet of archaeological heritage management. Described as a plan for minimizing the impact on archaeological remains from a proposed development, a mitigation strategy may involve works to ensure *in situ* preservation, archaeological recording of remains unavoidably threatened with destruction, or a combination of both approaches (Orton 2000). This clearly underscores the fact that mitigative archaeological fieldwork is generally considered as an indispensable part of CRM.

GIS weights of evidence predictive models are also designed to enhance land-use planning within regions of interest in Trinidad. Cleere (1989) asserts that land-use planning, as practiced in most countries relates to every aspect of the landscape. Human operation of all kinds—forestry, agriculture, road building, mineral extraction, industrial activity—can disturb the balance and degrade these aesthetic qualities, to the detriment of future generations. Therefore, a significant factor in any archaeological heritage management operation must be the establishment of close links and healthy collaboration among major players. Trinidad, especially in the south, has a welter of oil and natural gas mining installations, owned and operated by Petrotrin. Although sugar cane cultivation in Cipero and South Oropouche is predominantly controlled by small farmers, Caroni (1975) Limited, a government agency, exerts considerable influence on land-use management in relation to sugar cane production (Landell Mills Report 1992). Much of

the forested areas in Rest North are under the control of the Government Forestry Department. Through the coordinated efforts of the National Trust and the Archaeological Committee, GIS weights of evidence predictive models will furnish the above-mentioned agencies with the requisite knowledge to develop more effective land-use management strategies for the protection of archaeological sites in "high" and "moderate" favorability areas. The incorporation of new GIS data sets such as digital elevation models (DEMs), roads, land-use patterns, rivers and coastlines will enable cultural resource managers to produce a slew of new weights of evidence models for more effective site location predictions and land-use management.

Archaeological heritage management is also designed to protect the database for the academic discipline of archaeology. Archaeologists are always avid for data, both qualitative and quantitative. Without any form of heritage management the stock of sites would dwindle rapidly (Cleere 1989:9). Since the 1980s, Trinidad has been the scene of a number of archaeological projects conducted mostly by expatriates (Boomert 2000; Dorst 2001). In addition, the archaeological program at UWI was revitalized in 2001 with the employment of a full-time resident archaeologist. Given the constant need for archaeological data, an inadequate archaeological heritage management in a country with a relatively high level of development like Trinidad can quickly result in the almost total disappearance of the archaeological database without record. By digitally highlighting the most favorable pre-Columbian site locations, the weights of evidence models will provide an important database for scholarly archaeological research. New site discoveries and increased archaeological scholarship will also increase public awareness of pre-Columbian sites in Trinidad.

Effective management of cultural resources requires decisions about how resources can be best protected, preserved, utilized and interpreted. The exact decisions, as MacManamon and Hatton (2000) contend, require consideration of why the resource has been set aside for special treatment, its nature and significance, and the contemporary setting of the site. Available information about each of these matters should be marshaled and considered carefully in reaching the treatment decisions (MacManamon and Hatton 2000:9). The GIS predictive models generated in this dissertation will provide information not only about site favorability but also the various ecological variables with which these sites are associated. For example, the sum of weights for Cipero W2 (Table 5-23) clearly indicates that Land Capability (unsuitable for agriculture due to slope and/or water limitations has the highest weighted value [1.0168], followed by Relief (Rolling) [0.8103] and Landform (Uplands) [0.1501]. Armed with this knowledge, field archaeologists will be in a strong position to devise appropriate field survey strategies for identifying sites, through systematic field surveys, in the most favorable areas. Ground surveys and the examination of local exposures such as hillside embankments would be well-suited to "hilly," "upland" areas while field walking would be more appropriate for "flat" ploughed landscapes (Drewett 1999). Taken together with specific information about the size of the most favorable site location zones, the GIS weights of evidence models will enable cultural resource managers to make intelligent and informed decisions about tool, equipment, staffing and scheduling requirements for archaeological field surveys.

Archaeologists sometimes find hand-drawn maps paper databases cumbersome and difficult to integrate and manipulate (Wescott and Kuiper 2000). However, the weights of

evidence models will provide a powerful and efficient managerial tool for spatial data sets, allowing the field archaeologist the ability to access, analyze, and interpret large amounts of archaeological data in a fraction of the time previously required. New site discoveries can easily added to the database and used to run updated probability surface models on selected areas in Trinidad. If culturally significant sites are found, their attributes can be imputed into the GIS database. The field archaeologist will then report the site to the Archaeological Committee and the National Trust, recommending that the site be placed on the list of protected sites and monuments (Act No. 11 of 1991 Second Schedule).

Improved CRM through weights of evidence modeling will also constitute a big fillip to heritage tourism in Trinidad. Although the tourism sector contributes less than 3% of the GDP in Trinidad, attempts are now being made to develop sustainable tourism (Tewarie 1997:38). This is consistent with the commitment made under conventions such as the Rio Convention and the Summit of Americas (Tewarie 1997:38). Tourism with dignity is the linchpin of the country's tourism policy and this is reflected in elements such as selective exploitation of the tourism market stressing to the various target groups the uniqueness of the tourism product. Moreover, the policy seeks to preserve the national pride and dignity of the people of Trinidad and Tobago, while simultaneously encouraging foreigners to visit and experience the local way of life (Tewarie 1997:38). Trinidad's archaeological heritage can constitute a major plank in this cultural tourism. By helping to identify, protect and preserve pre-Columbian sites, the GIS predictive models will significantly buttress cultural resource management and stimulate heritage tourism.

However, the value of cultural tourism has been seriously questioned, largely because only a small proportion of international tourists primarily visit archaeological sites, monuments and art galleries (Cleere 1989:9). The value of such tours is also questionable; for the individuals concerned it is probably minimal, since they have little time to absorb even the basic facts about these important and complex sites. Nevertheless, there is an intangible benefit in that many tourists will be almost subconsciously influenced by a feeling of respect for the past and for the human achievement that the pre-Columbian sites in Trinidad represent. According to Cleere (1989:9) archaeological heritage managers should not be dismissive of mass tourism of this kind, since it can only serve to improve public attitudes towards their work, at the same time probably contribute financially to their continued work.

Last but certainly not least, more effective CRM through weights of evidence modeling will significantly improve public awareness of Trinidad's archaeological heritage, thereby helping to establish more coherent national identities. Lipe (1984:2) argues that value is not inherent in any cultural items or properties received from the past, at least not in the same sense as, say, size or color or hardness. Value is learned about or discovered in these phenomena by humans, and thus depends on the particular cultural, intellectual, historical, and psychological frames of reference held by the particular individuals or groups involved. This value can be effectively transmitted to the Trinidadian public at large through the media of television, books, movie films, class, lectures and museum displays that provide technical and non-technical information about the cultural resources. With the exception of the descendants of Carib Indians who reside in Arima, Trinidad to this day (Brereton 1989), the majority of Trinidadians being

primarily of East Indian and African ethnicities, have little cultural affinity to Amerindian traditions. Nevertheless, Trinidad's Amerindian legacy, as reflected in the myriad number of pre-Columbian and contact sites as well as place-names (see Baksh-Sooden 1986), is an important part of the country's cultural fabric. As pre-Columbian sites are increasingly identified through weights of evidence modeling, cultural resource managers will be better able to utilize the media and educational services to inculcate in Trinidadians greater national pride in relation to their rich and diverse cultural heritage.

Table 6-1. Archaeological Site Predictive Model (Cipero)

| | | | |
|---|---|---|---|
| PREDICTIVE MODEL | $p \geq 0.075$ | HIGH FAVORABILITY<br>7 $KM^2$ (14% OF WATERSHED) | LAND CAPABILITY (UNSUITABLE FOR AGRICULTURE DUE TO SLOPE AND/ OR WATER LIMITATIONS) LANDFORM (UPLANDS) |
| | $p \geq 0.0294$ | MODERATE FAVORABILITY<br>9 $KM^2$ (18% OF WATERSHED) | 1. RELIEF (ROLLING)<br>2. LANDFORM (UNSUITABLE FOR AGRICULTURE |
| | $p \geq 0.0$ | LOW FAVORABILITY<br>34$KM^2$ (68% OF WATERSHED) | LANDFORM (UNSUITABLE FOR AGRICULTURE)<br>AND/OR<br>NEGATIVE EVIDENCE |

Table 6-2. Archaeological Site Predictive Model (South Oropouche)

| | | | |
|---|---|---|---|
| PREDICTIVE MODEL | $p \geq 0.065$ | HIGH FAVORABILITY<br><br>23 $KM^2$ (5% OF WATERSHED) | 1. RELIEF (ROLLING)<br>2. LAND CAPABILITY (UNSUITABLE FOR AGRICULTURE DUE TO SLOPE AND/ OR WATER LIMITATIONS, SHOULD BE LEFT TO INDIGENOUS GROWTH OR FOREST)<br>3. LANDFORM (UPLANDS) |
| | $p \geq 0.0256$ | MODERATE FAVORABILITY<br><br>109 $KM^2$ (25% OF WATERSHED) | 1. LAND CAPABILITY AND LANDFORM OR<br><br>2. RELIEF AND LANDFORM |
| | $p \geq 0.0$ | LOW FAVORABILITY<br>306 $KM^2$ (70% OF WATERSHED) | LANDFORM AND/OR NEGATIVE EVIDENCE |

Table 6-3. Archaeological Site Predictive Model (Rest North)

| | | | |
|---|---|---|---|
| PREDICTIVE MODEL | $p \geq 1.08$ | HIGH FAVORABILITY 3 $KM^2$ (4% OF WATERSHED) | 1. LAND CAPABILITY (FAIRLY GOOD LAND) 2. SOIL TEXTURE (FINE SANDY CLAY) |
| | $p \geq 0.0224$ | MODERATE FAVORABILITY 20 $KM^2$ (25 % OF WATERSHED) | LAND CAPABILITY |
| | $p \geq 0.0$ | LOW FAVORABILITY 58 $KM^2$ (71% OF WATERSHED) | NEGATIVE EVIDENCE |

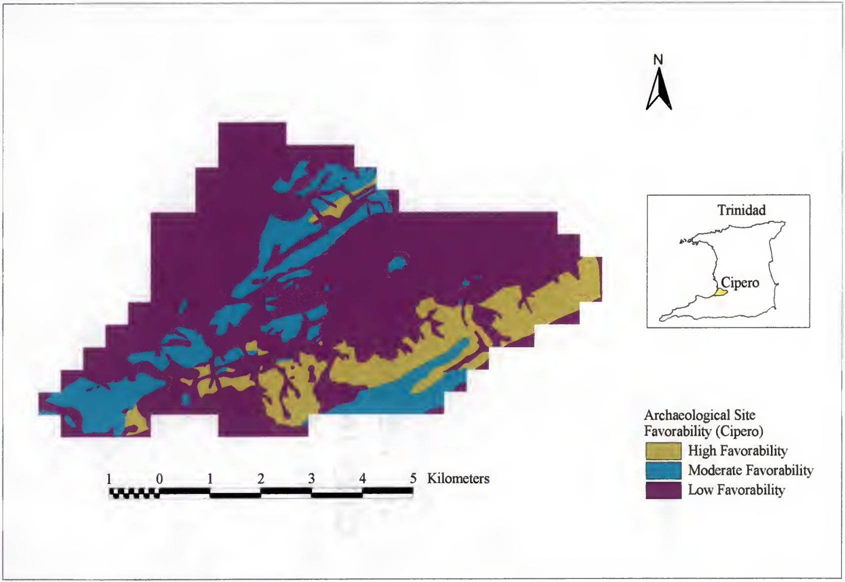


Figure 6-1 Archaeological Site Favorability (Cipero)

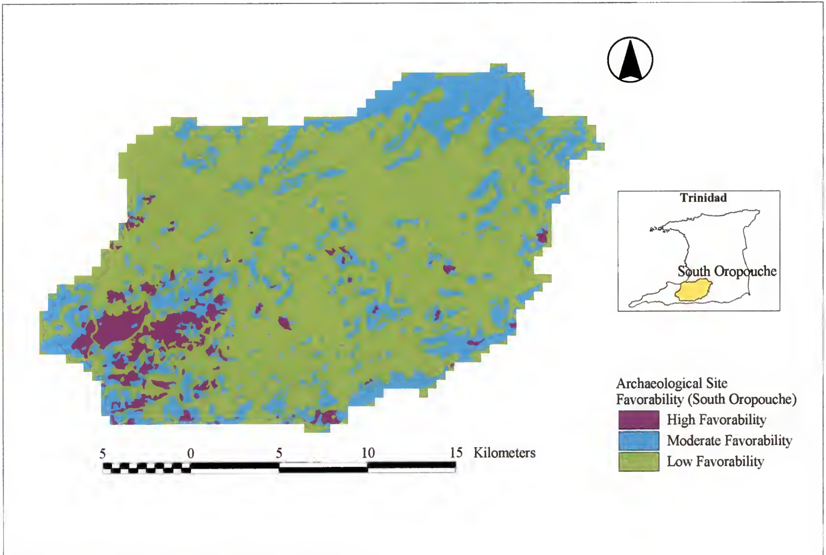


Figure 6-2 Archaeological Site Favorability (South Oropouche)

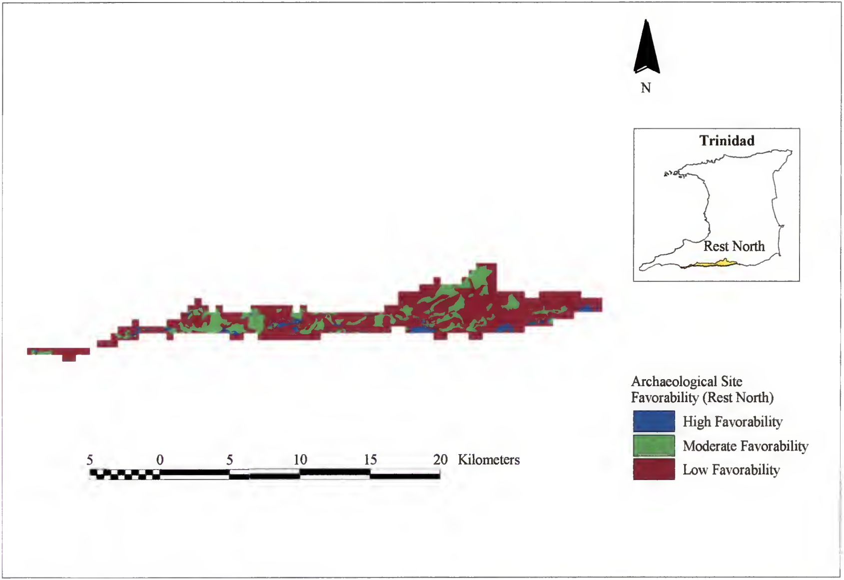


Figure 6-3 Archaeological Site Favorability (Rest North)

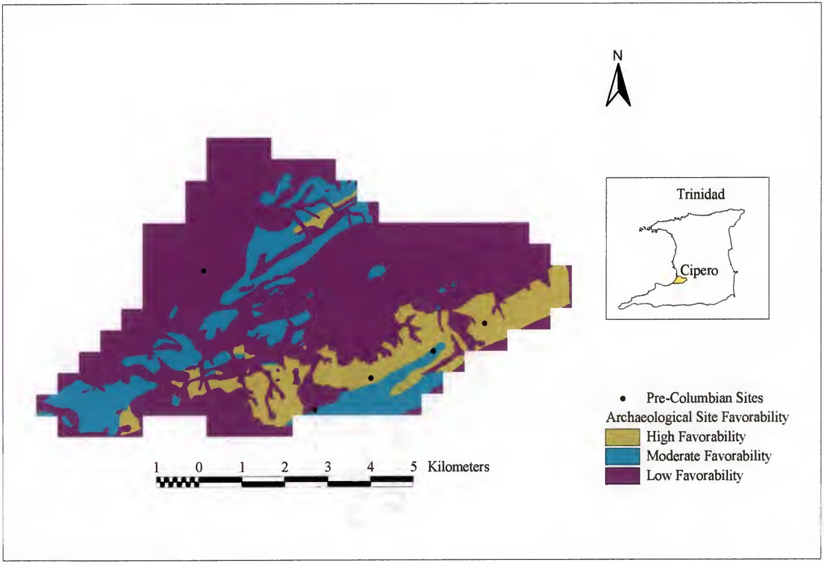


Figure 6-4 Archaeological Site Favorability (Cipero)

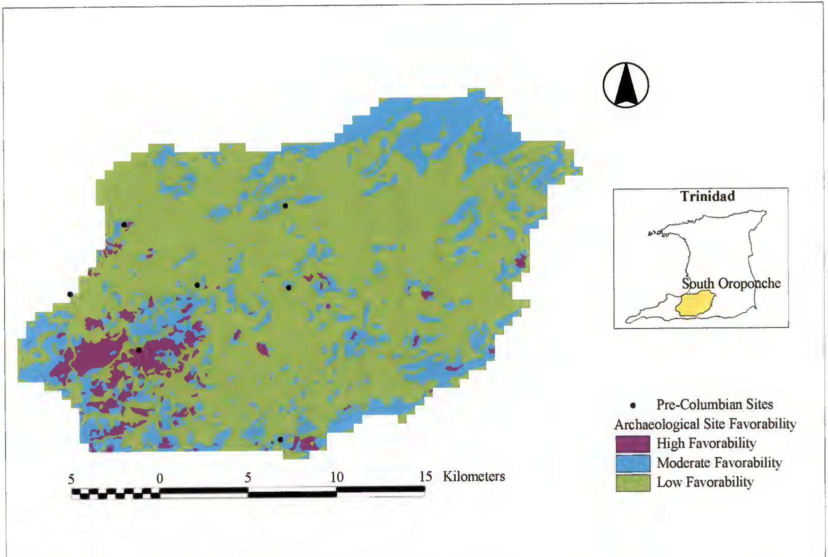


Figure 6-5 Archaeological Site Favorability (South Oropouche)

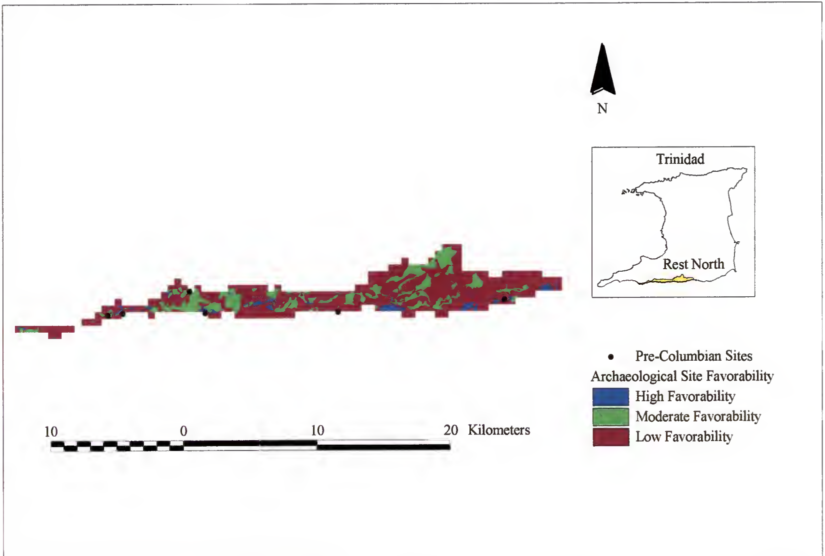


Figure 6-6 Archaeological Site Favorability (Rest North)

# CHAPTER 7
# CONCLUSION

Within the framework of GIS weights of evidence, this dissertation was able to produce three archaeological site predictive models for the watersheds of Cipero, South Oropouche and Rest North. Due to unsatisfactory conditional independence results, the Pilote watershed was not selected for the final weights of evidence models.

Among the items discussed in Chapter 1 was the desire to ably demonstrate the merits of applying GIS to small Caribbean environments where there is a rich array of cultural and biophysical features within a limited geographical area. This study represents the first attempt to clearly identify archaeologically sensitive areas on the island on the basis of GIS weights of evidence predictive models. Aimed at improving the cultural resource management of Trinidad's pre-Columbian sites, these predictive models constitute only a small area of the island of Trinidad and it is hoped that in the future, weights of evidence analysis will examine larger areas based on a greater variety of GIS data sets such as land use patterns, coastlines and digital elevation models.

Chapters 2 provided important contextual information on the island's natural environment. It is clear from this discussion that the pre-Columbian peoples of Trinidad were offered a rich food supply from a variety of microenvironments ranging from mangroves, swamps, rivers, forests to marine and coastal areas. The mild tropical climate, characterized primarily by wet and dry seasons, coupled with arable land in the central and south of the conceivably encouraged horticultural activity. While these

environmental descriptions of Trinidad are largely contemporary, they suggest that Trinidad was generally considered favorable for settlement positioning by several Amerindian groups who migrated from north-east South America and extensively occupy the island from 5000 BC to 1498.

A discussion of the history of archaeological research in Trinidad in Chapter 3 underscored the necessity of this dissertation. Despite the bold efforts of several amateur and professional archaeologists from the 19th century to the present to study and document Trinidad's prehistoric past, pre-Columbian archaeological research on the island continues to be largely be a collage of site inventories and stratigraphic profiles, slavishly couched within Rouse's time-space systematics. With Manzanilla research project being the singular exception (Dorst 2001, 2002), there is little or no information about inter-site and intra-site spatial relationships as well as the relationships between sites and the biophysical properties of the landscape on a regional scale. Given these realities, this GIS-based dissertation was necessary, as it provided predictive models for more clearly understanding the spatial relationships between pre-Columbian sites and Trinidad's multi-faceted ecology.

Chapter 4 highlighted many of the theoretical and practical underpinnings of this dissertation such as settlement archaeology, cultural materialism, geographical information systems (GIS) and predictive modeling. One of the key issues examined was that weights of evidence analysis, in spite of its shortcomings, determines the predictive "strength" of environmental features such as soil texture, land capability, and relief on the basis of the areal association between the training points and environmental data (Bonham-Carter 1994). When compared with most GIS predictive models, the weights

of evidence method allows certain variables to have more "predictive strength" than other variables, thereby producing a model that better reflects the decisions made by prehistoric people when choosing their activity areas.

Chapter 5 provided a step by step accounting of weights of evidence modeling, namely (1) selection of a descriptive model (2) selection of exploration (evidence) themes based on the descriptive model (3) refining the descriptive model based on the exploration (evidence) themes (4) selection of a training set (5) testing of the exploration themes to qualify them as viable (predictor) themes and (6) consolidating the themes into archaeological site location predictive models.

The results of weights of analysis were critically assessed in Chapter 6 with the major outcome being a revision of the original descriptive model of Chapter 5, which read as follows: *Pre-Columbian sites in Trinidad are likely to be found in areas with hilly relief in alluvial plains and valleys, in areas with very good to moderately good land capability and free internal drainage soils* to the following weights of evidence descriptive model: *Pre-Columbian archaeological sites south and southwestern Trinidad are likely to be found in areas with (a) hilly relief (b) land capability characterized by either fairly good land or land unsuitable for agriculture due to slope and/or water limitations (c) upland landforms and (d) "free internal drainage soils" along the south coast of the island.*

Also a major point of discussion in Chapter 6 was the important role of weights of evidence predictive models in Trinidad's archaeological heritage management. Among the salient issues was the value of weights of evidence analysis in (a) significantly reducing the monetary and time costs of fieldwork in the neotropics (b) land-use

management (c) devising appropriate field surveys strategies (d) creating and protecting database for the discipline of archaeology (e) developing a sustainable cultural tourism product and (e) fostering positive public attitudes towards Trinidad's Amerindian heritage.

## APPENDIX
## WEIGHTS OF EVIDENCE GLOSSARY

**Buffer** – A polygon enclosing an area within specified distance from a point, line or polygon. In ArcView/Weights of Evidence, buffering is performed using Spatial Analyst so that the output is always a grid (raster). The buffering function generates one or more buffers of equal distance from the input features. Input can be either vector or raster data.

**Categorical weights calculation** (analysis) - Refers to weights calculated for each class in an evidential theme. In ArcView Weights of Evidence, categorical analysis describes one of the tables of weights that can be created using the "Calculate Theme Weights" function, distinguishing it from "Cumulative Weights."

**Conditional independence** - Conditional independence of evidential themes with respect to the training points is assumed for the weights of evidence. The product of area and posterior probability summed over each unique condition is the number of points predicted by the model. A ratio is calculated by dividing the actual number of training points input to the model by this predicted number of points. The ration will be between 1 and 0. A value of 1 (never occurs in practice) indicates conditional independence among the evidential themes used in the model. Values less than 1 indicate a conditional independence problem although the values >.05 may produce reasonable results.

**Contrast** - Difference between weights, W+ and W-. Difference between the natural logs of conditional odds that A and B occur together and the natural log of the

conditional odds that A and B do not occur together. *C=In(Odds {B|A-});* where A = evidence layer; B = training set.

The contrast value of 1 and 2, respectively, approximate probability values of 0.75 and 0.88. The level of significance of contrast values is determined by the studentized contrast value. This is the contrast divided by its standard deviation. The approach used here is that a studentized contrast value of 2.0 is approximately equivalent to a 98% level of confidence.

The relationship of probability, odds and weight (natural logarithm of odds) are shown in the table (below).

| **Probability** | **Odds** | **Weight**[1] |
|---|---|---|
| 0.1 | 1/9 | -2.2 |
| 0.5 | 1/1 (even) | 0.0 |
| 0.75 | 3/1 | 1.1 |
| 0.88 | 88/12 | 2.0 |
| 0.99 | 99/1 | 4.6 |

**Cumulative weights (analysis)** - Refers to weights calculated for cumulative number of points for classes for ordered data. Cumulative weights calculated from either the highest to lowest (descending) or lowest to highest (ascending) class, can be calculated from a single evidential theme in the "Calculate Theme Weights" function. Refers to a method of calculating weights for cumulative distance intervals from a source (line, point, or polygon). Calculating cumulative weights can be useful in reducing noise from variation that occurs in categorical weights, making it easier to determine the optimum cut-off points for generalization of data.

**Evidence (predictor) theme** - This is a map or area layer (in either vector or raster format – shape or grid file) used for prediction of point objects (mineral occurrences or

[1] Also known as logit

archaeological sites). The polygons or grid cells of the evidential themes have two or more values (class values). For example, a soil map may have three or more values representing the classes (map units) present, for example land capability, soil texture and soil relief). Although weights of evidence was originally defined for binary evidential themes (also named binary patterns in several publications), it can also be applied to themes with more than two classes. Frequently, multi-class evidential themes will be generalized (simplified) by combining classes to a small number of values, facilitating interpretation.

**Missing Data Integer** - An integer required to define areas of missing data for each evidential theme, Each method handles missing data differently. The missing data integer is required even if missing data is defined by "No Data" or the evidential theme does not contain any missing data within the study area.

**Negative weight, W-** - Natural logarithm of the quantity: Odds that the evidence layer and training set do not occur together divided by the odds of training set occurring within the study area. *W = In(Odds{B|A-}/Odds{B});* where A = evidence layer; B = training set.

**Normalized contrast** - Contrast divided by the standard deviation of contrast.

**Pattern generalization** - In Arcview-WofE, the product resulting from reclassification of the thematic information of an evidential theme by classifying (grouping) existing classes in the theme attribute table to fewer classes in a new field.

**Positive weight, W+** - Natural logarithm of the quantity: Odds that the evidence layer and training set occur together divided by the odds of training set occurring within the study area. Difference between the unconditional or prior logit of A and the posterior

logit of A. A logit equals the *In* odds. *W+ = In(Odds{B\A*}/Odds {B};* where A = evidence layer: B = training set.

**Posterior probability** - A redistribution of the prior probability based on the weights.

**Prior probability** - Number of points in training set divided by the study area, expressed by the same area unit (cell size).

**Response theme** - An output map that expresses the probability that a unit area contains a training point, estimated by combining the weights of the predictor variable (evidence themes). The theme is based on a unique conditions grid and its attribute table

**Study area theme** - In Arc-SDM, the study area in an integer grid theme that defines the area of interest. It acts as a mask on areas of evidential themes and, if they are being used, training points outside the study are ignored during the calculation of weights and output maps.

**Training set or sites** – Point feature theme used in the calculation of weights. The set of spatial objects whose locations are to be predicted. The set of point locations is used to calculate the weights for each evidential theme, one weight per class, using the overlap relationships between the points and the various classes on the theme. The attributes of the training points are held in attribute table. Point subsets may be selected using the values of attributes, such as deposit size, or deposit type. However, points are treated as either present or absent in the model and not weighted by characteristics such as deposit size.

**Unique Conditions Grid/Table** - An important concept used in the Arc-SDM implementation of weights of evidence and logistic regression is the idea of a "unique

conditions" table and associated "unique conditions" map. This step is carried out in a grid format in Spatial Analyst, regardless of whether the evidential themes were input as vector or raster, but the concept applies equally in vector mode. The unique conditions table and map are produced by an overlay of the evidential themes selected for prediction.

**Unit cell area** - In weights of evidence and logistic regression, each training point is assumed to occupy a small unit area named the unit cell. In order to calculate the probability of a point occurrence, a unit of area must be selected. The output from the weights of evidence and logistic regression is a map showing the probability that a unit area contains a point. The values of the probability will chance with the choice of unit cell areas. The unit cell is a constant set at the beginning of a particular computer run, and is the same for all the training point and evidential themes. The area of the unit is unrelated to physical size or influence of points, and is independent of the grid size cell used in the raster data sets. The values of the weights in weights of evidence are relatively independent of unit cell area, if the unit area is small.

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## BIOGRAPHICAL SKETCH

Basil Anthony Reid was born on December 24, 1961, in Morant Bay, Jamaica. After completing his elementary school education at All Saints School in Kingston, Jamaica, Mr. Reid pursued his high school education at Ardenne High School, successfully completing subjects in the General Certificate of Education (GCE) at both the Ordinary and Advanced levels.

Mr. Reid matriculated at the University of the West Indies (UWI) in 1980. During his years as an undergraduate student at UWI, Mr. Reid participated in an archaeological field school in Drax Hall, Jamaica. Organized by the Jamaica National Heritage Trust in conjunction with University of California at Los Angeles (UCLA), the field school marked Mr. Reid's first exposure to archaeology and this experience propelled him to explore archaeology as a viable career path.

Upon graduating from UWI in 1983 with a Bachelor of Arts degree in history, Mr. Reid secured employment as a trainee archaeologist with the Jamaica National Heritage Trust in 1984. In 1986 Mr. Reid pursued a Master of Arts degree in archaeology at the University of London, Institute of Archaeology. After working with several cultural agencies (such as the Jamaica National Heritage Trust and Institute of Jamaica) as well as working as an assistant lecturer in archaeology at the University of the West Indies, Mr. Reid began doctoral studies in archaeology at the University of Florida in January 1998.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as dissertation for the degree of Doctor of Philosophy.

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May 2003

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